TILE DRAINAGE

James A. King

Tile Drainage

An explanation of how and why tile will benefit a large percentage of our lands and increase our INCOMES

Together with instructions for the proper installation of an efficient tile drainage system.

BY JAMES A. KING

Practical Farmer, Specialist on Tile Drainage for farms, formerly Professor in Extension Department, Iowa State College, assistant editor, "Farm Engineering" and managing editor "The Farming Business."

James A. King

A Statement by the Publishers

For several years we have realized the need for placing in the hands of land-owners a "Plain English" book on the subject of drainage—a book from which the technicalities of the usual text book would be eliminated.

We discovered Prof. Jas. A. King on the point of publishing the manuscript of this book. The first reading of the text revealed the fact that Prof. King's ideas and principles agreed with those we had held for years. We purchased the copyright rights to the manuscript and have published it in order to do our part in making known the great material benefits which the average farmer or land-owner may expect from properly tiling his farm.

Prof. King was born and raised on an Iowa farm. He spent two years in the Extension Department of the Iowa State College, at Ames. For four years he managed large farms in the wet areas of Iowa. For the past ten years he has been identified with drainage work and the Iowa State Drainage Association. He has been assistant editor of "Farm Engineering," and managing editor of the "Farming Business." At present he is managing his own farm in Mitchell County, Iowa, and writing for the leading farm papers of Iowa and Minnesota.

With such a wealth of practical experience in drainage and an unusual facility for telling others what he has personally experienced, no one is better qualified to state the real facts regarding drainage and to give reliable advice upon this important subject.

Prof. King's ideas upon the proper methods of drainage, its benefits and what is the proper tile, match up so perfectly with our own that we have taken the liberty of inserting a chapter at the end of this book to bring to your attention the merits of our product.

Mason City Brick & Tile Co.

By B. C. Keeler

Mason City, Iowa
Sept. 16, 1918

Author's Introduction

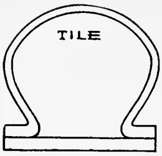
Drainage is of two kinds. Sanitary drainage, or sewage disposal, is the drainage of surplus water and liquid wastes from cities and towns for sanitary reasons. Land drainage is the removal of surplus surface or soil water from land to make it available for farm uses.

Sanitary drainage or sewage disposal is as old as is the habit of human beings to live in settled communities or towns. The earliest known method of sanitary drainage was by means of open surface ditches. This method is still used in such backward portions of the world as is India and China, where house sewage may be seen being conducted thru the streets in open surface ditches.

The use of covered ditches, instead of open ditches, is in itself a very ancient practice. The first covered sewage ditches of any permanence were made by the use of flat stones to form a covered channel in the bottom of the ditch, then filling the rest of the ditch with dirt. The use of hard burned clay pipe, made in short lengths much as our sewer pipe and drain tile of today, is as old as the ancient art of pottery. Sewer pipe made of hard burned clay have been unearthed in the island of Crete; still whole and serviceable after being in the ground for nearly seven thousand years, ever since the year 5,000 B. C.

Hard Burned Clay Sewer Pipe laid in Island of Crete 5000 B. C. and still in perfect condition.
—Courtesy Clay Products Association

One seems to be justified in moralizing with the philosopher of old, "There is nothing new under the sun." For Cato, an ancient Roman author, in the year 200 B. C. discussed quite extensively the subject of farm drainage as practiced by the Roman farmers of his time. And centuries before that, the exact time of its beginning is unknown, the farmers of Egypt and of Babylonia drained their wet lands in order to make them yield crops of larger quantity and better quality.



Pallet

End view of Horse Shoe Tile, the first drain tile made.

So far as known, the first farm drainage was accomplished by means of open ditches. But even before the time of Christ, Roman farmers, and farmers of other countries bordering on the Mediterranean Sea, were using covered drainage ditches. These were made by digging the necessary ditches thru the wet areas of a farm, placing brush, sticks or stones in the bottom and then covering them with the soil. Thus it is seen that mere surface drainage of overflowed lands was soon followed by subsurface drainage which was designed to remove the surplus water from the soil itself.

These ancient farmers soon found that these subsurface ditches, which were filled with sticks, twigs or stones and covered over with dirt so as not to interfere with working the fields, filled or clogged up so they did not work so well. This led to building a channel in the bottom of the ditch with flat stones of more or less regularity in size and shape, which did not clog up so readily because there was a continuous open channel thru which the water could flow unimpeded. The chief fault to be found with this type of ditch was that too large openings existed between the stones because of unavoidable irregularities in their size and shape. So that these also would fill up in time, tho not so quickly by years as did those more ancient types of covered ditches.

Even the use of clay tile for land drainage is not a new thing, not by several hundred years. The farmers of France are given the credit of being the first to use clay tile for the construction of farm drainage ditches. They used a modified form of the medieval clay roofing tile for this purpose. A cross section or end view of one of these tile resembled a horse shoe, and they are known as "horse shoe tile" because of this resemblance. A flat piece of burned clay the length of a tile, called a "pallet," was laid in the bottom of the ditch and a tile was then laid on top of it with its open side down. Thus the pallet closed the open side of the horse shoe shaped tile and so made a closed tube for the water to flow thru. The exact date when these clay tile were first used for land drainage in France is not known, but is supposed to have been not later than the fourteenth or the fifteeenth century.

The use of clay tile for farm drainage became a lost art in France, forgotten and unknown to her farmers for many generations. In the seventeenth or the eighteenth century it was again developed in England. The same horse shoe shaped tile, modified from the shape of the clay roofing tile, was also the first form used in England. These tile were first made by hand, and consequently were very costly. The first machine for making drain tile was developed in England in 1841. This greatly reduced the cost of drain tile, and correspondingly increased their use.

John Johnston, of near Geneva, New York, was the first man to tile land in America. At great expense he imported hand made, horse shoe shaped, burned clay tile from his native Scotland in 1835. His neighbors came from many miles around to view this "something new

under the sun" and to tell him that they would poison and ruin his land. But when the wheat crops he reaped from his cold clay soil increased from ten or fifteen bushels an acre to forty and even fifty bushels an acre some of them were convinced that maybe he was not a fool after all. Some very few even following his example. The result was that in 1848 one of those English machines for making tile was imported into this country. By 1851 Johnston had sixteen miles of tile ditches on his farm. These tile which were laid seventy to eighty years ago are still working successfully and the old Johnston homestead is one of the finest farms in that part of New York, one of the historic places of that state.

So you see that farm drainage, and even clay tile drainage, is not something new and untried. Land drainage is as old as the written history of the world. The use of clay tile for sanitary drainage or sewage disposal is also as old as is the written history of the world. And the use of clay tile for farm drainage is several centuries old. Until very recent years tile drainage has been confined to "wet" lands. Its purpose has been only to remove surplus water from land too wet for the production of tilled crops. But in recent years it has been realized that tile will very materially benefit soil which is not ordinarily considered to be "wet." More progressive farmers are now tiling high ground which the ordinary man does not consider needs tiling, and they are finding that the investment so made is returning big dividends. Soils which are "tight," but not "wet;" soils which are "cold," but not "wet" respond very markedly to tile drainage. They loosen up and become mellow to the depth of the tile ditches, thus permitting deeper penetration by the plant roots and a more free circulation of air thru the soil; they become warm and "quick;" all of these increase greatly the rapidity of crop growth and the quantity and quality of yields.

There can be no mystery, no sorcery or witchery, about anything which has been practiced so long as has farm drainage. Of course, all that can be known about it is not yet known. But all that is needed to be known about it to convince any reasonable man that it is a good business investment to tile his land is already known. The effect on his crops, and on his net income, is well known, and is proven by centuries of actual practice. Surely, no sane man needs any more argument than that to convince him.

This little book has been written for the purpose of presenting to the farmers of this country in a very brief and simple way the argument why they cannot afford not to tile their farms. Much of it has been written to explain in that same simple manner the processes by which tile drainage increases the quantity and the quality of the crops which are grown on the land. Still more of it has been written so that my brother farmers may know the fundamental principles involved in planning and in constructing a good and efficient system of tile ditches to meet the conditions existing on their farms.

It is written for farmers who own land which is not paying its owners as large profits as it should pay them, because it is not producing crops of as large yields or as high quality as it is able to, or should, produce. It is written by a farmer who has worked wet, un-

tiled land; who has tiled it and then worked it after the tile have done their duty. It is written by a farmer who has made an extensive study of the theory, and an extensive observation of the practice and the results, of land drainage. It is not written to make money for the author, for only those who write interesting fiction make money out of books. It is written to make more money for those who read it and follow the advice given in it. It is written to do the author's best to serve his nation in this crisis by helping to increase our food supply, when he is unable to serve by wearing the khaki as he once wore it.

The author realizes that the subject of "What Tile To Use" is one which has been avoided religiously by other authors writing on the subject of tile drainage. But my own experience taught me the importance of the subject of what tile to use, and the difficulty I had in answering the question for myself showed me how difficult it is for any one to get reliable information on it. The quality of the tile buried in the ground will make or ruin a drainage system, it will make or break the man who makes the investment. He should be, and is, vitally interested in that part of the subject of tiling; fully as much as in any other part of it. It is a question which the average man is unable to answer for himself, and he finds it very difficult to find any unbiased advice or opinion on the subject. The Professors of our colleges and experiment stations always avoid or side step the question for fear of possible criticism of their motives. Realizing the importance of the question, I have discussed it frankly and fearlessly in the last chapter of this book, under the title of "What Tile To Use." I am simply a farmer, with no "professional dignity" to preserve; I am writing this book for the benefit of farmers; I feel that this book would be incomplete and unsatisfying to its readers without a discussion of this subject. So I have discussed it and expressed my views frankly and without any apology other than this explanation of my reasons for doing so.

JAMES A. KING.
Otranto Station, Iowa
1918.

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CHAPTER I.

Tile Benefits In a Nutshell

Increases the tillable acres

Tiling makes the best land out of your worst. The wettest land on your farm is the richest. The richness of higher ground washes down onto it and lodges there. But that richness is no good to you because you can't work it. Tile that wet land and it is no longer wet. But it is ideally moist for growing crops. It is that way all the time. What was your worst land, is now your best. What was your most useless land, is now your most useful. What was earning you nothing, is now earning you the most.

It is much cheaper to tile out the wet parts of your farm than it is to buy another farm just like it, to increase your tillable acres. The University of Minnesota reports its experience of this kind. The tillable land of one of the University farms cost $129.72 an acre. The wet land was tiled at a cost of $61.50 an acre. So that tiling increased the tillable acres at less than one half the purchase price of land which was no better, to say the least.

Increases the yield from tillable acres

Many an untiled quarter section is producing no more than is a neighboring eighty which is well tiled, but which is no better in any other way than is the quarter section. If that quarter section were tiled it would produce as much as a half section of the same kind of land it was before it was tiled. The annual production of the farm would be doubled without increasing the cost of that production.

Increases the quality of all farm products

Profits from a farm are regulated largely by the quality of its products. High quality products bring higher prices than do those of inferior quality. Tiled fields produce high quality products every year. Untiled fields produce good quality crops only in very favorable seasons. Tiled lands pay profits every year. Untiled lands pay profits only occasionally.

The farms which earned profits in the wet years of 1915 and 1917 were the ones which produced crops of good quality as well as of large quantity. Those farms were well tiled. The farms which failed to earn profits those years were the ones which produced crops of very inferior quality, regardless of their quantity. Those farms were the ones most in need of tiling. The same rains fell on the tiled fields as fell on the untiled. The same cold winds blew across the one as blew across the other. The same amount of sun shone on the untiled fields as shone on the tiled. But the tiled fields produced larger yields, and of far better quality, than did the untiled fields. And so the tiled fields paid profits, while the untiled did not.

Decreases the labor costs of production A good seed bed is prepared with less labor in well tiled land than in untiled land. Crops are kept well cultivated with less labor on well tiled land than on untiled land. The yield is larger per acre on the well tiled land than on the untiled. So that the labor cost is not only less per acre, but it is a great deal less per bushel or per ton.

Decreases overhead cost of production Few men figure overhead cost, but it is a fixed charge which should be deducted from the gross income before crediting a year's business with a profit. Where the land is well tiled, and so is producing at full capacity, the interest on the money you have invested in land is spread over a larger production of crops and of livestock than where part of your land is so wet as to be partly or entirely useless and unproductive. The interest and depreciation on the investment in machinery, buildings and other improvements is also spread over a larger production of crops and of livestock. This makes your overhead charge for interest and depreciation per unit of crop or livestock production smaller on well tiled land than on untiled land.

A close-up view of a part of the field shown on page 3. This photograph shows the wet, swamp-like condition before the land was tiled and shows why it paid no income to its owner.

Increases the value of your farm More of the farm fortunes of today have been made from the increase in the market value of the land than have been made by a gradual accumulation of the net profits from working the land year after year. By tiling the wet acres on your farm you increase its selling value, because you have increased its producing value. The amount of that increase will be greater than the cost of the tiling.

Tiling increases the renting value of your farm. By increasing the yield from a farm you increase the share rent you get. By increasing the yielding ability of a farm you increase the cash rent you can get for it. Mr. John Horrigan had been renting his farm near Plymouth, Iowa, for three dollars an acre. He tiled the entire farm at a cost of thirty dollars an acre. Since tiling it he has gotten seven dollars and a half an acre rent for it.

View of field part of which is shown on page 2. This photograph of an excellent crop of flax, after the land was tiled, was taken two months after the one shown on page 2.

CHAPTER II.

When Tiling Is Necessary

When crops start slowly On practically every farm there will be found fields or spots where the seeds sprout slower than on the rest of the farm, or in the rest of that field. This is because the surface layer of soil in which they have been planted is cold and wet, and is lacking in air; all three of which interfere with the proper germination of the seed. Either the subsoil, or the surface layer itself, is so tight that the surplus water cannot escape before it has done damage to the germination of the seeds.

When crops do not grow well The stalks of the plants are smaller than they should be. They are slender and spindling, the leaves are narrow and thin instead of being broad and thick. The color of them is a pale yellowish green, instead of being a rich dark green. In no respect are the plants as tall, large and rugged as they are on the other parts of the farm. This is all indisputable evidence that the soil needs tiling.

When crops fire in dry weather The crops growing on untiled ground are the first anywhere around to show damage from drought. First the leaves wilt. They are not as crisp and fresh looking as in other parts of the field or farm. Then they begin to roll up, rolling from the edges in toward the midrib. In all respects they show droopy and wilty. At the same time, the surrounding crops on well tiled land are fresh, crisp and full of life. That plot of ground is suffering from the effects of having had too much soil water during the early part of the season. The roots could not penetrate deeply enough to have access to a deep supply of moisture in these later stages of their growth. So they are the first to suffer from dry weather. This in itself is sufficient proof that such a plot of ground needs tiling.

Kind of weeds which grow there If the most vigorous growing weeds found on a plot of ground are those which grow best in wet soil, then that plot of ground needs tiling. If it did not need tiling, then you would not find these weeds growing there more luxuriantly than any other place—and than any other weeds growing there—as they cannot grow and thrive well in a soil which is properly tiled, or naturally drained, for the production of maximum yields of our standard grains and forage crops. The following are among the most prominent and common of these weeds which are found on our mid-western farms: Joint weed. Quack grass. Devil's Shoestring, a large growing type of smartweed. Sorrel. "Little Pine." Plantain.

If the soil is at all tight Any field, or part of a field, needs tiling if the soil or the subsoil is at all tight. Such soils will produce larger and better crops year in and year out if they are tiled than they will if they are not tiled. It matters not whether the tight soil or subsoil is in a level or rolling field; whether it is on a hill top or at the bottom of the hill. As a heavy rain falls, the water is not soaked into these tight soils fast enough to keep it from standing on top or running off. It it stands on top it drowns out the crops and interferes with the preparation of plant food. If it runs off the surface of a rolling field, it washes away the mellow surface soil. In either case it cannot store a good supply of capillary water.

When there are springy places By a springy spot is meant a place where the soil remains wet and tough after the soil on all sides of it is dry, or the excess water has disappeared from it. These springy spots may be found on the top of a hill, on the side of a hill, at the foot of one, or out in the middle of a comparatively level field. They indicate that there is below them a layer of tough and impervious ground which the water cannot penetrate. Instead, it moves along the top of this tight layer until it finds a place at or near the surface where it makes its appearance.

When there is standing water Of course any one knows that a plot of ground or a field needs tiling when water stands on the surface after a rain. But it also needs it just as much if the water stands near the surface for any length of time. If you cannot judge as to this from the condition of the crops growing on the surface of the ground, then you should dig down into the soil and the subsoil and examine it for the depth of the water table. There does not need to be water standing in the bottom of the hole you dig to indicate that the water table is there. The very fact that the soil is so wet that the imprint of your fingers remains in a lump of it after squeezing it tight is proof enough. If there is any question in your mind as to whether or not the soil or the subsoil is tight, the question may be settled easily. Dig a hole to the depth of a foot. Fill this hole with water and see if the water stands in it for any length of time. Dig holes to the depth of two feet, of three feet, and of four feet. If the water stands for any length of time in any of these test holes then the soil or subsoil below the surface of the water is too tight for the best production of crops. It needs tiling.

Corn on Tiled Land

These photographs were taken on the same day in adjacent fields in which the soil conditions were exactly the same except for the difference made by proper drainage. The field in the photo above was tiled the year before, the one in the photo below was not tiled. Compare the height of the corn with Mr. King, who is just under 6 feet tall.

Corn on Untiled Land

CHAPTER III.

How Tiling Gives The Proper Water Supply

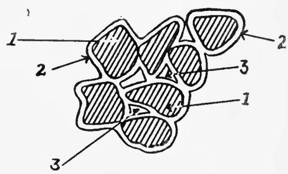
Water requirements Water is the most widely influential single factor in producing the best conditions for plant growth and development. If only the proper amount of water is in the soil, practically all other things necessary for the production of a crop are in prime condition. If there is too much water, or not enough of it, in the soil then these other things are also out of proper condition. The water supply is quite completely under our control, and at a very small annual cost per acre. Therefore it is most deserving of our very careful consideration.

Soil water is best classed and discussed under two main heads; capillary water, and gravitational water. Capillary water is that which clings to the surface of the granules of the soil. Gravitational water is that which fills up the open spaces between the granules of the soil when it rains, and then runs down thru the open spaces of the soil and away—if it has the chance.

Capillary water dissolves the food contained in the particles of the soil. The roots of the plants absorb this food laden water and conduct it to all parts of the plant where its load of food is taken from it and used for building up the tissues of the plant. This water is to the plants what the blood of an animal is to its body. It is the one kind of soil water which is of direct benefit in the production of a crop.

As it sinks down thru the soil during and following a rain, the gravitational water restores the supply of capillary water by re-wetting the granules of the soil. It is very beneficial if it comes frequently enough and in sufficient quantity to keep up the proper supply of capillary water. But it is very harmful if it stays long enough to keep the air out of the soil for more than twenty-four to forty eight hours; it smothers the plant roots and the soil bacteria, and makes the soil cold.

For the production of maximum crops, the soil should contain approximately fifteen to thirty-five per cent of its own weight in water in the capillary form. Professor Jeffery, formerly of the Michigan College of Agriculture, states that sandy soils should contain an amount of water equal to fifteen per cent, loams twenty per cent, clays thirty per cent and the finer clays thirty-five per cent of their dry weight. These quantities should be kept as constant as possible during the periods of seed germination and plant growth.



Showing what is meant by "Capillary Water," and "Gravitational Water." 1. Represents individual grains of soil highly magnified. 2. Represents a film of capillary water surrounding each grain of soil. 3. Represents the air spaces between grains of soil when there is no surplus or gravitational water to fill those spaces.

The following table shows the amount of capillary water used in the production of different yields of five of our leading field crops, this table being a modification of the reports of the late Professor F. H. King of the Wisconsin College of Agriculture.

Crops and Yield Per Acre	Water Needed	
	Inches per acre	Tons per acre
20 bushels of wheat	6.0	680.0
35 bushels of wheat	10.5	1190.0
40 bushels of oats	6.27	710.6
65 bushels of oats	10.19	1154.0
30 bushels of barley	6.42	727.4
45 bushels of barley	9.63	1091.4
40 bushels of corn	6.72	761.5
65 bushels of corn	10 92	1237.0
100 bushels of potatoes	2.07	234.62
300 bushels of potatoes	6.2	702.6

Notice carefully the amounts of water which these crops remove from the soil in producing these different yields. In producing one hundred bushels of potatoes to the acre, the plants use up enough water to cover each acre of ground slightly over two inches deep. In producing sixty five bushels of corn to the acre the plants use enough water to cover the ground almost eleven inches deep. Remember that the water so used by the plants is only the capillary soil water, that which clings to the surface of the granules or individual particles of the soil. This table shows the great importance of making the proper provision for storing an abundance of capillary water in the soil where the roots of the plants can get it. Such provision is made only by thoroly tiling the land, as is explained in succeeding paragraphs of this chapter.

Removes the surplus water There are only two ways in which the gravitational or surplus water can escape from the soil. It must escape thru the subsoil, or be evaporated into the atmosphere. The latter is a very slow process, and uses up heat which should be stored in the ground. The rapidity with which the first process acts depends upon the character of the subsoil, the slope on which it lies, and the natural outlets to which it leads.

Nature has not furnished in the various grades of clay, loam and peaty or muck soils, or in their subsoils, the necessary channels and outlets thru which this gravitational water can escape as rapidly as it should for the good of the crops growing in those soils. Until such channels and outlets are furnished, these soils are "sick" and unproductive. The remedy must be provided by man before these soils can possibly produce maximum crops at a maximum profit. The best known method of furnishing such outlets, and developing the necessary connecting channels thru the subsoil, is to do a good job of tiling.

Tiling furnishes channels in the subsoil to which the surplus or gravitational water can run quickly and naturally, and thru which it can escape into the open streams or natural outlets. These tile ditches remove the surplus water which results from a rain storm be-

fore it has remained in the soil long enough to do any damage to the crops in the various ways which are explained more in detail in succeeding chapters of this book.

Increases the supply of available capillary water The amount of capillary water which is available for the use of the plants depends upon the following factors: (1) The depth to which the plant roots penetrate into the soil and subsoil. (2) The surface area of the particles into which the soil and subsoil is divided, for it is the surface of the particles to which the capillary water clings. (3) The amount of water which is supplied to the soil thruout the season for the purpose of restoring the supply of capillary water.

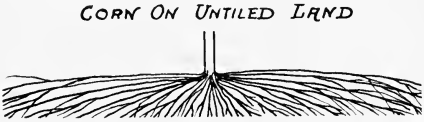
In a poorly drained soil the gravitational water stands near the surface during the spring season when the root systems of the plants are being formed. Plant roots cannot grow and live in the absence of air. So they do not penetrate down into this portion of the soil or subsoil in which gravitational water stands for any length of time. The result is that in such soils the roots of the plants are confined to a shallow upper layer of soil. When dry weather continues for any length of time this top layer of soil in which the plant roots are confined dries out and the growth of the crop is seriously retarded if not stopped entirely for the want of sufficient water.

But in a well drained soil the gravitational water does not stand for any length of time in the upper few feet of soil or subsoil. Then as the root systems are being formed they are able to sink as deep as it is their nature to sink, because they can find the supply of air which they must have. It takes a much longer and more severe dry spell to evaporate all the water from the entire layer of soil which is occupied by the roots of the crops, than it does in the case of crops growing on poorly drained land.

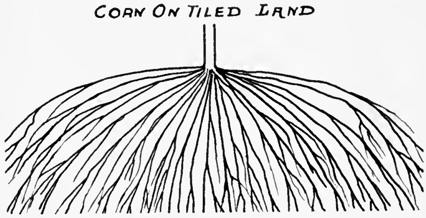
The result is that crops growing on a poorly drained field "fire" quickly when a dry spell comes on. While those crops which were planted on a well tiled soil continue to grow vigorously for a long time and successfully and without injury, withstand a much longer continued dry or droughty spell than do those planted on a poorly drained soil.

The total area of surface of soil particles which is wetted by capillary water is much greater in a well tiled soil than in a poorly drained one. The processes of alternate wetting and drying to which the soil is subjected thruout the year determine the number of particles into which the soil and the subsoil are broken up, and this determines

CORN ON UNTILED LAND



CORN ON TILED LAND



This drawing shows how tile increases the available supply of moisture in dry seasons by increasing the depth to which plant roots penetrate in the spring season.

the amount of surface area which is made available for water to cling to. (By drying, is not meant the total removal of water from the soil, but simply the removal of gravitational water from the open spaces of the soil so that air can enter in the place of the water.) The well tiled soil is dried out in this way after each rain. The poorly drained soils are often not dried out in this way from the time of one rain to the time of another, probably only a few times thruout the season.

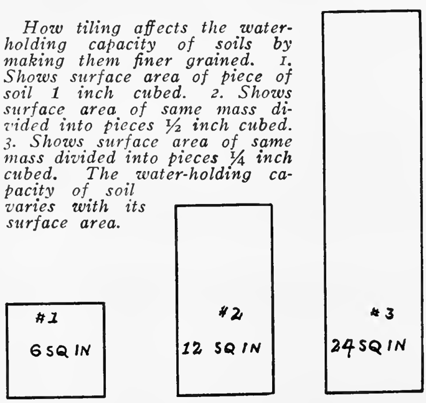
So that the well tiled soil is far more thoroly pulverized than is the poorly or undrained soil. It containes more open spaces and a much larger total surface area of soil particles than does the untiled soil. Consequently, as the gravitational water resulting from a rain storm sinks down thru such a soil it soaks up more of that water, and retains it in the form of capillary water, than does the untiled soil. The well tiled soil will contain more actual pounds of capillary water to the cubic foot than will the untiled soil.

The result is that the roots of the plants growing in a well tiled soil not only have access to more cubic feet of soil than do those growing in an untiled soil. But they also have access to a soil which contains more capillary water to the cubic foot than does the untiled soil. So that tiling such a tight soil which is not properly drained by nature enables it to store up from the rains a much larger supply of available capillary water for the use of the plants during a season of drought than it was able to store away for such use of the plants before it was tiled.

Restores the capillary water in dry seasons Tiling permits the supply of capillary water to be restored to the soil in a dry season when there are no rains. While it takes the unnecessary water out of the soil in a wet season, it also brings the necessary water into the soil in a dry season. Sounds fishy, doesn't it? Well, it isn't fishy; it is facts. And here is the explanation of how it works:

The ability of air to hold moisture increases or decreases with the temperature of the air. Warm air will hold more water or moisture than will cold air. If the air is only partly filled with moisture, and you cool it down low enough, you finally reach a point where it is "running over full," and it has to drop some of its moisture. This is just what happens when it rains; a cold wind runs into a warm, moist one and cools it down to a point where it cannot hold all of its water, but has to give it up in the form of rain.

On hot days the soil is colder than is the air above it. In well tiled soils there is a constant movement of air thru the entire layer of soil above the tile. In dry seasons the air which is blowing across the fields already contains a large percentage of moisture, even tho it is still able to absorb



How tiling affects the water-holding capacity of soils by making them finer grained. 1. Shows surface area of piece of soil 1 inch cubed. 2. Shows surface area of same mass divided into pieces ½ inch cubed. 3. Shows surface area of same mass divided into pieces ¼ inch cubed. The water-holding capacity of soil varies with its surface area.

more moisture because of its high temperature. As it filters thru the soil it becomes cooled, by coming in contact with the cooler soil thru which it is moving. Finally before it again escapes from the soil it has been cooled to a temperature low enough so that it is forced to give up some of its moisture. This moisture is deposited on the surface of the particles of soil with which the air is in contact. This restores, to that extent, the supply of capillary moisture in the soil thru which the air is circulating. It is just as tho a little rain storm or a dew had taken place within the soil itself.

Thus a well tiled, porous soil is kept more moist in a dry season than is the same kind of soil which is not well tiled, and thru which the air cannot circulate so freely. The extent to which the supply of capillary water is thus restored will depend upon the freedom with which the air circulates thru the soil. The lines of tile greatly increase the rapidity of this circulation of air thru the soil, just as ventilating flues facilitate the circulation of air thru a building.

The author observed a very striking illustration of this effect of tile drains in a system which he installed in a very wet farm a few years ago. The system was completed by the first of June. That summer was a very hot and dry one. When it came time to do the fall plowing, that clay soil was very hard over most of the areas lying in between the lines of tile. It was difficult to hold the plows in the ground, and the soil was turned up in large chunks and lumps, the plow being unable to pulverize it. But for a distance of several feet on both sides of each line of tile, the soil was mellow and moist; it plowed easily and the plows pulverized it into a fine, mellow condition. Also the aftergrowth in the stubble on these moist, mellow strips of soil was much heavier and greener than in the rest of the fields.

At that time the system had not been installed long enough for the air passages to be increased in all the soil lying in between the adjacent lines of tile. That is the reason the moist condition was found only near the lines of tile. In succeeding years, the area so effected spread until in time the entire areas in which lines of tile were laid were in the same condition and show the same action in a dry season.

Thus, by doing a good job of tiling, we are able to control the supply of moisture in the soil which is available for the use of plants to a much greater extent than nature herself is able to control it. We are able to remove the surplus water from the soil in times of an over supply. And yet we are not robbing the soil of any useful water which would have been stored in it by this surplus for the future use of the plants; in fact, by removing it, we actually increase the amount of useful water stored in the soil by it, which is available for the use of the plants during future times of need. Furthermore, we enable Nature to increase the supply of useful water in the soil during drouthy seasons when there are no rains to store it in the ordinary manner adopted by Nature. Laying tile in the ground is not going against Nature, it is actually helping her in the various ways she works to keep crops supplied with their necessary supply of soil moisture. We are helping her do her work in both wet seasons and in dry seasons.

CHAPTER IV.

How Tiling Gives The Proper Heat Supply

Heat needed for seed germination There is a certain temperature for each of our crops below which their seeds will not germinate. There is also another temperature above which each kind of seed will not germinate. Somewhere in between these two extremes there is found a temperature for each kind of seed at which it germinates most quickly. This best temperature is generally near the highest rather than the lowest temperature at which the seeds will germinate at all. The colder the soil, the longer it takes the seed to both start and complete the process of germination.

The accompanying tables show how the temperature of the soil—not of the air above the soil—effects the germination of several different kinds of seeds. These temperatures have been determined by experiments made at the leading experiment stations of the world. The latter of these two tables brings home very forcibly the importance of having the soil good and warm when the seeds are planted or sown in it.

RANGE OF TEMPERATURES AT WHICH SEEDS HAVE BEEN FOUND TO GERMINATE.

SEED	Lowest temp. at which seed was found to germinate	Temp. at which the seed germinated the quickest	Temp. above which seeds would not germinate
Wheat	41 Fahr.	81 Fahr.	104 Fahr.
Barley	41 "	83 "	104 "
Peas	44½ "	84 "	102 "
Corn	48 "	93 "	115 "
Squash	54 "		115 "
Red Clover	42 "	70 "	

DAYS REQUIRED FOR THE FIRST SPROUT TO COME OUT OF THE SEED WHEN THE SEEDS WERE KEPT AT THE TEMPERATURES INDICATED IN THE TABLE

SEEDS	Days required at the temperatures indicated below			
	41 degrees	51 degrees	60 degrees	65 degrees
Barley-wheat	6 days	3 days	2 days	1¾ days
Beans	7 "	6½ "	4¾ "	4¼ "
Red Clover	7½ "	3 "	1¾ "	1 "
Flax	8 "	4½ "	2 "	2 "
Corn		11½ "	3¼ "	3 "
Oats	7 "	3¾ "	2¾ "	2 "
Peas	5 "	3 "	1¾ "	1¾ "
Pumpkin			10¾ "	4 "
Rye	4 "	2½ "	1 "	1 "
Sugar beets	22 "	9 "	3¾ "	3¾ "
Timothy		6½ "	3¼ "	3 "

Examine very closely the number of days required at the different temperatures of the soil for wheat, barley, clover, corn, oats and

sugar beets to germinate. Notice that anywhere from five to nineteen days may be lost from the total growing season of these crops because the soil is too cold to give their seeds a good start. These five to nineteen days are lost from the most vitally important part of the growing season.

In a series of tests covering a period of five years, made at the same latitude as northern Iowa, it was found that at no time did the monthly average soil temperature equal any of the temperatures shown in the second column of the first table—the ones at which the various seeds germinated the quickest. Not until June did these monthly average soil temperatures reach sixty degrees. During April the temperature averaged thirty-five and forty degrees. During May it averaged about fifty-five degrees. A poorly drained soil will have a temperature considerably below these averages which were determined for the soils of state agricultural experiment stations, which are always above the average in quality. It is only well tiled soils which will give temperatures equal to these averages, which are still below those needed for the best germination of the seeds.

Heat needed for the plant growth The nitrogen fixing bacteria which live on the roots of clover, alfalfa, and other legumes live and work best at a soil temperature of ninety to one hundred degrees. There are other kinds of bacteria which prepare the food elements of the soil for the use of the plants; these live and work best at a soil temperature of eighty-five to ninety-eight degrees. They work only slowly when the temperature of the soil is below fifty-four.

The plant roots absorb water most rapidly at soil temperatures of from 80 to 95 degrees. At temperatures of fifty and sixty or below they absorb water much more slowly than at these higher temperatures. This is why plants growing in a warm soil will appear to be almost bursting with the water they contain—are luscious, crisp and brittle—when the same kind of plants growing at the same time in a cold soil will be limp and lacking in moisture content, will be practically wilted.

Thus we see that the temperatures at which the soil bacteria work best are also the temperatures at which the crops themselves feed most rapidly. The result is that the soil temperatures at which our standard field crops grow most rapidly lie between eighty-five degrees, for wheat and ninety-three to ninety-five, for corn. This is several degrees higher than the average temperatures of our soils during the principal growing season of April to September. Therefore it is very important that we should do everything in our power to aid the soil in receiving and storing all the heat it can. The principal way in which we can do this is to keep all the surplus water out of it.

How heat is stored in the soil The chief source of the heat found in the top layer of soils in which our plants grow is the sun. As the sun's rays shine upon the surface of the soil they cause it to become warmed. A field sloping to the south will be warmed more than will one sloping to the north, for the amount of heat "deposited" in the soil depends upon how nearly to the perpendicular the sun's rays strike its surface. If the surface of the soil is mellow and finely pulverized more heat will be stored in it than if it were rough and cloddy. These lumps or clods reflect a part of the sun's rays and so keep them from entering the soil. Some

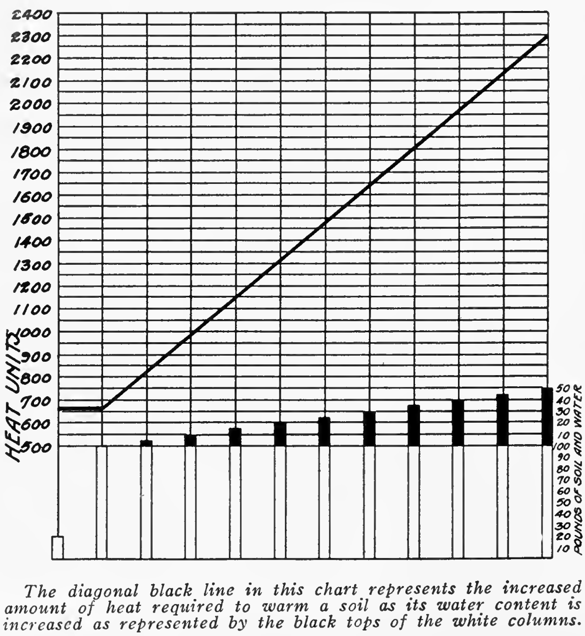
of the heat which does enter the lumps of dirt is deflected and given off from them into the surrounding air instead of into the soil beneath. If the larger lumps rest on still smaller ones, so that there is a cushion of air between the larger lump and the soil beneath, this air cushion prevents heat from being transmitted from the lump down into the soil below.

As the sun's heat penetrates into the soil it warms up, or raises the temperature of, the soil and the water which it contains. Naturally the top layer of soil is warmer than is that below it. Only the heat which is stored in the upper layer of soil passes down into the lower layers of soil or subsoil. If a large amount is stored in the surface layer, there is much to be passed on down into the subsoil; if only a small amount is stored in the surface layer, there is only a little available to pass on down into the subsoil.

We have what are known as warm soils and cold soils. This difference is due to the character of the soils themselves rather than to any difference in the amount of sunshine which reaches either of them. The warm soil is warm because a large amount of the sun's heat is absorbed by it. The cold soil is cold because only a small amount of heat from the sun has been absorbed by it. The amount of water which may be contained in a soil is the chief factor in determining whether or not it is able to absorb heat from the sun. Now let us see how this works.

How water affects the amount of heat absorbed by the soil

By experiment it has been found that the amount of heat required to raise the temperature of one pound of water one degree is sufficient to raise one degree the temperature of four pounds of dry peat, and five pounds of sand, clay or loam soils which are perfectly dry. Also, the amount of heat required to evaporate one pound of water is sufficient to raise one degree the temperature of 966.6 pounds of water. This means that in evaporating one pound of water enough heat has been used up to raise one degree the temperature of 3,866 pounds of dry peat or 4,833 pounds of dry sand, clay or loam soils.



The diagonal black line in this chart represents the increased amount of heat required to warm a soil as its water content is increased as represented by the black tops of the white columns.

Since it requires more heat to warm up water than it does to warm up soil, then

it also requires more heat to warm up a wet soil than it does to warm up a dry soil; the wetter a soil is, the more heat is required to raise its temperature one degree. So that the "Warmth" of a soil, on a certain day, will depend upon the amount of water which it contains; a dry soil will be warm, while a wet soil will be cold, even tho the same amount of sun's heat has shone upon the two of them. Our principal soils are in the best condition for the germination of seeds and the growth of plants when they contain the following amounts of capillary water, and no surplus or gravitational water; sand, an amount of water equal to fifteen per cent of its own dry weight; loam, twenty per cent; clay, thirty per cent; fine clay, about thirty-five per cent. So it requires approximately two and one half times as much heat to raise the temperature of one pound of surplus water as it does to raise the temperature of one pound of properly moistened soil the same amount. And the amount of heat required to evaporate one pound of surplus water would raise the temperature of about 2,400 pounds of properly moistened soil one degree.

The accompanying chart, prepared by Professor Jeffery, formerly of the Michigan College of Agriculture, illustrates very forcefully this effect of the water content of a soil on the amount of heat required to raise its temperature. This chart takes into account only the problem of warming the surplus water in the soil, not of evaporating this surplus water.

Surplus or gravitational water, which must be evaporated to be gotten rid of, is the chief factor which keeps a soil cold. All heat used in evaporating this surplus water is lost so far as warming the soil is concerned. We can understand somewhat the reason for this when we remember that the heat consumed in evaporating one pound of this surplus water would warm over 2,400 pounds of normally moist soil one degree. A series of tests made at the Wisconsin State Experiment Station, and covering a term of years, shows that the heat used during twenty-four hours in evaporating the water from a wet soil is enough greater than that used in evaporating water from a normally moist soil to raise the temperature of the top one foot layer of that normally moist soil twenty-four degrees.

This is heat which is lost from the wet soil. It is heat which is stored in the normally moist soil. Being used up in evaporating this surplus water from the wet soil, it is never again available to aid in the production of a crop on that ground. Stored in the normally moist soil and its subsoil, it is fed back again into the surface soil—and into the air above it—for the use of the crops growing on it during a series of cold days when the sun is not giving heat to the soil.

Any crop trying to grow on that wet soil is retarded at the time it is wet because the air is driven out of the soil. It is also retarded later on because the soil has been robbed of that much heat which it should have stored up as a reserve to be used from later when a cold snap comes.

The heat lost by a wet soil in one day is in itself a serious matter. But think how much worse it becomes if it is overly wet for several days at a time, and several times during the year. The total amount of heat lost by that wet soil in one year is equal to this loss of one day multiplied by the total number of days in the season that the soil

is wet and the heat of the sun is being used to evaporate this surplus water rather than for warming the soil. It is bad enough for one day only. But by the end of the season it has grown into a calamity.

No wonder a wet soil is cold. No wonder crops grow slowly on it and give only light yields of poor quality—especially corn. No wonder well tiled soils are warm by contrast and give much larger yields of much better quality.

How to make a cold soil warm A soil is "cold" because the heat delivered to it by the sun is used in evaporating surplus water from it, rather than being stored in the soil. In the same way a man is poor if the money he earns is spent for something which does him no good rather than being deposited in a savings bank or being invested in something which will bring him an income. In order to make that soil warm we must remove that surplus water from it in some other way than by evaporating it with the heat from the sun. If we remove this surplus water as rapidly as it comes into the soil the heat of the sun will be used in warming up the soil itself.

The one successful way to do this is to tile all land which is wet or "cold." The tile will remove the surplus water from the soil as rapidly as it enters from a rainstorm. In fact, all clay, loam and peaty soils are much better off for having a thoro and complete system of tile, even tho we do not consider them to be "wet" soils. The gravitational water percolates down thru them slowly at best. They also gradually open up these soils so that the water settles down thru them more rapidly. Thus the tile change a cold soil into a warm one by permitting the sun's heat to be used in warming the soil rather than in warming or evaporating unnecessary water which would stand in the soil until evaporated if it were not for the tile.

CHAPTER V.

How Tiling Gives The Proper Air Supply

Why air is needed Seeds will not germinate without air, it is absolutely necessary for the chemical processes which take place within the seeds during germination. Seeds planted in a water logged soil from which all air is excluded absorb the water which is necessary for germination. But if air is not admitted to the soil and the seeds within a few days after they are planted no other part of the process of germination will take place, and in time the seeds mold or rot and so entirely lose their ability to germinate. If air is admitted to them before they have entirely lost their vitality they will germinate. But their germination and the succeeding growth of the young plants will be much slower than if the proper supply of air had been present when the seeds were planted.

Roots cannot feed the plants if there is no air in the soil; they must have air or they cannot absorb the food laden water of the soil. If they are robbed of air for a few days, the roots will die; they drown just as an animal drowns, tho not so quickly. If all of the roots die, the entire plant will die. If only a part of the roots are drowned, the entire plant will not die but it will be weakened and its development retarded because it cannot get as much food as it needs.

Food cannot be prepared for the use of the plants without the presence of air in the soil. These plant foods are prepared for absorption by the roots by the action of certain kinds of soil bacteria. These must have air or they cannot do their work. The nitrogen fixing bacteria which live on the roots of clover, alfalfa, and allied plants get their nitrogen from the air contained in the soil. They must also have the oxygen of pure air or they can not perform their work of storing or fixing nitrogen in the root nodules.

In the soil there are certain bacteria which have the unusual ability to "manufacture" oxygen for their own use when there is no fresh air admitted to the soil to supply it to them. They attack the nitrates which have been prepared for the use of the plants by other bacteria. They decompose these nitrates and take the oxygen from them for their own selfish uses. Thus these bacteria become oxygen thieves when they get oxygen hungry. Professor Jeffery reports that soils which contained large quantities of nitrates have been found to contain hardly a trace after being in a water logged condition for three days.

The germination of seeds and the growth of plants use up and foul the air of the soil just as the breathing of animals uses up and fouls the air in a building. The foul and exhausted air of the soil must be replaced with fresh, pure air just as it must be replaced

in a building containing animals or human beings, and for the same reason. If this ventilation of the soil is not carried on continuously, or accomplished quickly at frequent intervals, the plants will die.

So improper ventilation of the soil does damage in these ways: The absence of all air prevents the germination of seeds and the feeding of the plants, by their roots. If continued long enough it will kill the roots of the plants. The lack of fresh air retards the germination of seeds and the growth of plants. Either the absence of all air, or failure to replace old air with fresh, will cause the destruction of the nitrates, one of the most important classes of plant foods found in the soil.

How air enters the soil The very weight of the air itself causes it to sink down into the soil when there are open spaces for it to enter. If the barometer falls, so that the air becomes lighter and less dense, some of the air rises out of the soil. Then when the barometer rises, so that the air becomes heavier and more dense, fresh air sinks down into the soil again. This action in itself will produce a little movement of air thru the soil from day to day.

As the soil becomes warmer, due to a hot sunshiny day, the air contained in it expands and some of it rises out of the soil. When the soil cools again at night the air contained in it shrinks, thus making more room which is filled with fresh air from above ground.

The blowing of the wind across the surface of the field causes the air to move into and out of the soil to a greater or a less extent. The natural tendency of the air to slowly move back and forth, up and down, and around causes a certain amount of circulation of the air thru the soil.

The forces mentioned in the above three paragraphs will, alone, produce satisfactory ventilation in the thinner upper layer of surface soil if it is open and porous and is not crusted over so as to prevent the passage of the air. But its effect is not so great on the air contained in the lower layers of the soil known as the subsoil. This subsoil must have a good "airing out" about ever so often just as we find it necessary to air out a house or a barn, or to draw a few deep breaths, occasionally. The gravitational water resulting from a good rainstorm is what gives the subsoil this necessary occasional airing out.

As the surplus water from a rainstorm sinks down into the soil it fills up the pores or open spaces of the soil. This forces the air out of the soil. Then as the gravitational water disappears from the pores of the soil, fresh air comes into it to take the place of this water. In this way all the old air is driven out and a completely new supply of fresh air is admitted to take its place.

How tile help this ventilation Tile ditches furnish outlets thru which the air can escape readily from the lower level of the subsoil as it is being driven out by the descending water. This prevents the formation of an "air cushion" in very fine grained soils which would tend to retard the descent of the water. This permits the water to descend into a fine grained subsoil more rapidly than it can when there are no tile ditches in it.

The tile also furnish channels thru which the gravitational water can escape after it has performed its two functions of restoring the supply of capillary water and driving out the dead air from the soil. It should not be permitted to remain in the soil an hour after doing these things; every hour it remains, it is doing damage in some one of the ways already mentioned. It does no good to drive out the old air if no fresh air is admitted in its place, and this is just what happens after a heavy rain in untiled clay and loam soils.

Tile make these fine grained, tight soils, more porous so that the air and the water sink into them more rapidly, and so the air circulates thru them more readily and easily, thus aiding in this important work of ventilating the soil. This is how tile do this:

When a wet clay or loam soil dries out, it shrinks. This shrinkage produces cracks which run in different directions thru the soil and produce passages for the air and the water. The next time the soil is saturated with water, it swells out into and fills up these cracks. If the surplus water stands very long, the soil becomes recemented into one solid mass. When it dries out again, it again breaks up into only about the same number of chunks and forms only about the same number of passages as before.

If tile ditches are placed in such a soil to remove the gravitational water as rapidly as it reaches them, the water will not remain long enough to recement the soil into the one solid mass. As it dries out after a wetting, each of the former pieces into which the soil has already been divided is broken up into several smaller ones. Finally, after a year or so—depending on the character of the soil, this alternate wetting and drying of these well tiled soils will cause them to become finely pulverized. This pulverizing of these tight soils thus increases the rapidity with which water sinks into and escapes from the soils; this, in turn, increases the rapidity with which the foul air is replaced by fresh air.

CHAPTER VI.

How Tiling Increases The Available Plant Food Supply

Sources of plant food The more important elements used as plant foods are carbon, oxygen, hydrogen, nitrogen, potassium, phosphorous, calcium, magnesium, sulphur, chlorine and iron. The carbon is obtained from the air, being taken in thru the leaves of the plant in the form of carbon dioxide—a combination of carbon and oxygen. The needed oxygen and hydrogen are obtained from the soil water, or from the air in the soil. All the others are obtained from the soil in the form of various compounds, combinations with other elements. They are dissolved by the capillary water of the soil and then absorbed by the roots and conducted to all parts of the plant in the same way in which our blood conducts the necessary nourishment to the various parts of our body.

The bulk of these food elements contained in the soil are in such a form, or exist as such compounds, that they cannot be dissolved by the soil water, or at least such that they cannot be used by the plants. Nature provides means in a good soil for changing these into compounds which can be dissolved by the capillary water and used by the plant. The chief means thus provided is a variety of bacteria which live in the soil. As these carry on their regular life processes and activities, they change these compounds into other compounds which can be used by the plants. We have already learned how the supply of air and of heat in the soil effect the activities of these soil bacteria.

How tile increases the available food supply We have already learned how tile increase the warmth of the soil and stimulate the ventilation or replenishing of the air supply. By increasing the heat and the fresh air in the soil the activity of these soil bacteria is stimulated. The result is that more food is made available for the use of the plants in a well tiled soil than in a similar soil which is not well tiled. By supplying plenty of fresh air, the tile prevent the oxygen thieves, or the "denitrifying bacteria" from decomposing the nitrates, or nitrogen compounds which have been made ready for the use of the plants, and so robbing the plants of this very necessary food. Thus it is seen that tile will increase the amount of food which is made available for the plants in each cubic foot of the soil.

Tile also increase the total number of cubic feet of soil from which the plants can obtain food. The tile keep the gravitational water out of the soil to a greater depth, and admit heat and air to a greater depth, than in untiled land. This permits these food preparing bacteria to live in a deeper layer of soil. It also permits the roots of the plants to penetrate to a greater depth than they can in an untiled soil of the same character.

Thus it is seen that tile increase the available supply of food in two ways. The amount of food which the plants can use is increased in each cubic foot of soil. The number of cubic feet of soil in which the food is prepared, and thru which the plant roots penetrate in their search of food, is increased. So tiling a field increases the yields of crops obtained from it by increasing the supply of food made available for the use of the plants.

CHAPTER VII.

How Tiling Effects The Growing Season

Lets you Plant earlier Tiled ground is ready to plant as soon as the weather warms up in the spring. Surplus water is removed from the ground without delay. All of the available heat of the sun is used to warm up the soil, none of it is wasted in evaporating surplus water from the soil. You never have to wait for a tiled field to dry out so you can work it. As soon as the frost is out of the ground in the spring the soil is dry enough for you to plow it or do any other work which is necessary to get it ready for planting or seeding. As soon as the season has advanced far enough to do away with all danger of damage by frost or freezing, the field is dry enough and warm enough for you to put the seed into it. You may have to wait on the weather man, but you never have to wait on the ground. And that is certainly a great relief to you in a backward spring.

Lets you cultivate quickly Within twenty-four hours or less after a heavy rain storm you can go into a well tiled field and cultivate it. For fields of untiled tight soils, such as the clays and loams, you have to wait several days before you can get into them with a cultivator. This permits the tiled fields to be cultivated more often than can the untiled fields. This more frequent cultivation keeps the weeds down better, conserves better the moisture in the soil and stimulates the growth of the plants more. This increases the rapidity of the growth of the plants and so increases the effectiveness of the available growing season.

Keeps the plants growing all the time Plants growing in well tiled soil never stand still for the want of heat, air or food. Every day of the season they are right on the job, busy at their task of growing and producing a crop of grain or of forage. But those which are growing in an untiled field have to stand still for one or more days after each rain. The surplus water standing in the soil keeps out the air which they must have in order for the roots to absorb food laden water. Those days that the soil is cold because the heat of the sun is being used to evaporate surplus water from the soil, instead of furnishing its heat to the soil, to the food preparing bacteria, and to the plant roots, the growth is very slow if there is any at all.

The result is that crops on untiled fields cannot grow all of the days of the growing season, while those on well tiled fields are busy every day. There are many days when the crops on untiled fields grow only very slowly, but those on well tiled fields grow rapidly every day; the only factors left to effect the rate of their growth are the

fertility of the soil and the warmth of the air, factors which have the same effect on the untiled fields.

The sum and substance of the matter is this: Tiling advances the growing season; it permits you to prepare and plant a field sooner than you can an untiled field the same season and in the same community; this gives you an actually longer growing season for your crops, and increases its length in the spring when plant growth of the bulk of our standard crops is most rapid. It gives the plants a quick start; this makes them strong and vigorous so that they grow more vigorously all the rest of the year; a quick start gives a strong growth and a large yield. It gives them more active growing days than have crops planted in an untiled field. So that tiling lengthens the growing season, lets the crops grow each day of that longer season, and makes them grow more vigorously each day than they can on untiled fields.

CHAPTER VIII.

How Tiling Reduces Costs of Production

Cost of production The only cost of production which most men figure is that of labor. Many count as a labor cost only that labor which they have to hire, they figure wages for their own labor as a part of the profits of the business. But this is not correct, you should figure wages for yourself and all other members of the family just the same as you figure wages for the help you have to hire. And these wages of yourself and the other members of the family should be deducted from the total or gross income from the business before you figure any of your income as being profits from the business.

What are known as overhead costs make up a considerable list of charges which should also be deducted from the gross income before you begin to count profits. These overhead costs include the following charges: Interest on the total investment, whether in land, buildings, machinery or equipment of all kinds. Taxes and insurance. Depreciation on buildings, fences, machinery and equipment.

Then added to these labor and overhead costs are the costs for seed, fertilizers and so forth. These are actual charges against the costs of producing a crop whether we buy them or produce them ourselves. And all of these costs are the same whether the yield from the land is large or is small. What is known as the unit cost of production is determined by dividing the total cost by the total units of production, the total number of bushels or tons of the product.

How tiling effects labor On a well tiled farm all the fields are regular in shape. They are not cut up by sloughs, pond holes and wet spots. This makes a very material difference in all the labor operations involved in the production of a crop from a field. The author had experience with one fifteen acre field which had fourteen sides to it, because of two irregularly shaped sloughs which cut into it. This irregularity in shape of this field increased the labor required on it fully twenty-five per cent over what it would have been had the owners tiled it so as to give a regularly shaped twenty acre field.

The soil of the tiled field is mellow, that of the untiled field is tough and the footing for the horses is heavy. The result is that horses and men can do more work in a day in the well tiled field than they can in the untiled one. Fewer operations are required to make the soil fine and mellow for the planting of the seed. It requires less work to keep down the weeds on tiled land than on untiled; the more troublesome weeds do not grow on it, and you can get onto the ground

at any time so as to kill the weeds while they are still small and easily killed. The tiled ground will give larger yields than will the untiled, and so the labor of harvesting or gathering the crop will be somewhat greater—especially in the case of corn. But this increased cost of harvesting will be practically balanced by the saving in the labor of production.

Increases production and so decreases unit costs

What is called the unit cost of production is the cost of producing each bushel or each ton, or other unit of measure, of the crop produced. This is determined by dividing the total cost of production by the total number of units of the crop produced. So that a large production will give a low unit cost of production, while a small yield will give a large unit cost of production.

Tiled land will give larger yields than will untiled lands. It will do this without increasing the gross or total costs. Therefore tiled lands give a crop at a lower unit cost of production than do untiled lands. The price you receive for a crop is the same per unit, per bushel or per ton, whether you have a large yield or a small yield. So the tiled land will give you larger profits than will the untiled land.

Summary of Tiling Benefits

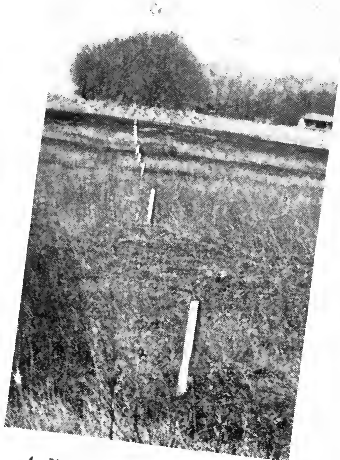
The benefits which result from doing a good job of tiling may be summed up very briefly as follows:

1. It gives the proper water supply.
2. It gives the proper heat supply.
3. It gives the proper air supply.
4. It increases the available supply of plant food.
5. It advances the growing season.
6. It lengthens the effective growing season.
7. It increases the rate of growth.
8. It increases the tillable acres of your farm.
9. It increases the yield from your tillable acres.
10. It increases the quality of all your field products.
11. It decreases the labor cost of producing your crops.
12. It decreases the overhead cost of producing your crops.
13. It increases the value of your farm.

These benefits are not confined to swamps and excessively wet land, only. They are to be had from tiling well done in any tight soil. It is a mistaken idea that tiling is beneficial only on very wet lands. It will take only a few years for the increased income to repay all costs of tiling a field which is ordinarily considered to be a pretty fairly dry field.

Steps in the Installation of an Efficient Tile Drainage System.

Never undertake a job of tiling without the supervision of good drainage engineers.



A line of stakes set by the engineers for the guidance of the diggers.

Digging the first spading true to a line.

Cleaning out after the first spading and throwing the fine, black dirt out by itself to one side of the ditch.

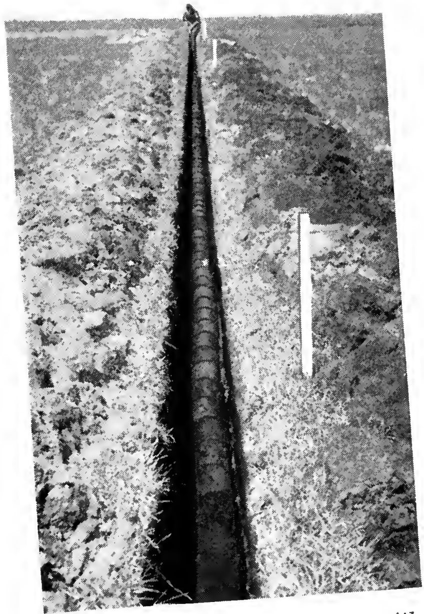
Digging the second spading.

Digging the third spading to put the tile good and deep.

Cleaning and shaping the bottom ready to receive the tile.

Gauging the bottom of the ditch to insure it is the right depth and the fall is uniform.

Laying the tile.



The ditch should be straight, without any twists or crooks in the line of tile.

Blind covering the tile with black dirt as soon as they are laid.

The line is all covered and the end tile plugged to keep out dirt and animals.

A tile system with the main ditch dug up a central drain, the laterals coming into it from both sides on the "Herring Bone" plan.

Digging the ditch by machinery. A very good, and a labor-saving way. But always lay the tile by hand—never by machinery.

Filling ditch with a disc harrow. A quick and good way, as the dirt is well pulverized—no big chunks.

CHAPTER IX.

How Tile Work

How water moves through soil The natural tendency for water is to move straight down. This is due to the action of the force of gravity. This force pulls the water downward thru the soil just the same as it makes the rain or any other object fall to the surface of the earth.

But the particles of soil with which the drops of water come in contact on their downward journey interfere with them, they are obstacles in the path of the drops of water. The water cannot pass directly thru these particles of soil, it travels only thru the channels or open spaces between them. So when it strikes one of them, it moves to one side or the other until it finds a continuation of the channel which leads downward. In this way the water tends to move downward in a slanting direction, rather than perpendicularly.

Why soil is wet This surplus water keeps on moving downward until it reaches a layer of earth so tight and impervious that it is unable to pass thru it. If this tight layer is practically level there is no means for the water to escape. If the rains are heavy enough and frequent enough, this upper layer of soil becomes saturated with water. The only escape for it is the slow process of evaporation. The entire area of level land underlaid with this layer of tight subsoil must be tiled or it will always be too wet to grow crops successfully.

If this tight layer has any slope, the water moves down along its surface until it reaches the lowest point available. As the water moves down along this sloping surface of the impervious layer, it is joined by other water which has sunk downward from the surface of the soil above it. This naturally adds to the amount of water which moves along the next section of this tight layer. Finally a point is reached where this accumulation of soil water is so great as to completely saturate the soil clear to its surface, even without the addition of any more water coming down from above. This point may be reached long before the lowest point of the slope has been reached.

This is because the soil water has to move a considerable distance horizontally in getting even a short distance downward. It is also because it must move slowly, rather than freely as in an open stream. This slowness will depend upon the slope of the tight layer of subsoil and upon the character of the soil thru which it is moving. In any case a point is finally reached where the soil must be relieved of this accumulation of slowly sideways moving water or it will appear as a wet spot on the surface of the slope, and all that portion of the slope below it will be wet for the same reason.

How this is overcome Lines of tile furnish subterranean passages or channels for the removal of this soil water before it has had a chance to accumulate in sufficient quantity to do damage. These tile ditches furnish channels thru which the water can escape more easily and quickly than by evaporation from the surface of the level land, or than by making its way slowly along the surface of the tight subsoil in the sloping land. Water is like everything else, it always moves along the lines of least resistance, or those which offer the least difficulty to its movement.

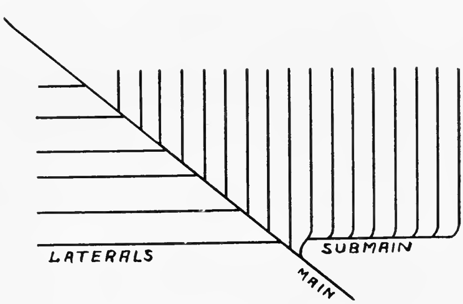
Some times a few lines of tile will collect all of this water and each line deliver its collection direct to the natural outlet. But in most cases there is no outlet to which each ditch can deliver its accumulation of water without carrying it a considerable distance thru ground which has no need of tiling. In such cases they are all made to dump their individual accumulations of water into one larger tile ditch which then carries it all to the outlet. This is much cheaper than to have each of the ditches extended to the natural outlet. These individual ditches are then called "laterals" and the one larger ditch is called a "main."

Again it often happens that there are several wet spots, all of which finally feed into the same natural outlet. A set of laterals is laid in each of these wet spots, and these are connected into a larger ditch for each wet spot. All these larger ditches or mains from the different wet spots then empty into a still larger ditch which carries the accumulated water from all of them to the natural outlet cheaper than all of the smaller mains could have been extended to the outlet. In this case the largest of all the ditches is called the "main" and the smaller main ditches are called "submains."

Of course the submains and the main each collect water from the ground on each side of them, just as do the laterals, when they pass thru ground in need of tiling. Thus they perform the duty of a lateral thru the ground in which they are laid as well as performing the duty of mains in carrying to the outlet the water which has been collected by the laterals connected into them.

Water table The "water table" is the bottom of the layer of soil from which the ditches collect or draw water. Or it may be described as the top of the layer of subsoil from which they are unable to draw water, and which is then left permanently wet.

This water table is never level. Out halfway between the lines of tile, it is higher than immediately over them, or close to them. This is because the soil interferes with the horizontal or side ways movement of the water even more than with the downward movement; the strongest force which is acting on it is the force of gravity which is pulling it downward. This results in the surface of the water being curved rather than perfectly flat.



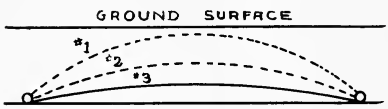
Map of a tile system which shows relation of mains, sub-mains and laterals.

The degree or the roundness of this curve will depend upon the character of the soil. In a very fine grained clay soil, thru which the water moves slowly and with great difficulty, the surface of the table will be more sloping than in a more open soil thru which the water can move with greater ease. The highest point of the table will be half way between two adjacent ditches. In a tight soil this highest point will be nearer the surface than in a more open soil.

This is why a system of laterals will drain a mellow soil thoroly when placed further apart than they will in a tight soil. It is why they will "draw further" in an open or mellow soil, such as a sandy loam or a jointed clay, than in a pure clay soil. They will not only draw further, but they will also draw faster, than in the tighter soil.

When a system of drains in a very tight soil is new, this table has a steep slope back from the tile ditches. For several years this slope becomes more gradual or flat until the highest part of it finally reaches a point much nearer the level of the tile in the ditches than when the system was first put in. This is why, the first one to three years of its life, a system of tile does not show as good effect on the ground furthest from the ditches as it does on that close up to them. But after the system has been in long enough for the high point of the water table to reach its permanent lowest point no difference will be noticed between the crop growing immediately over the tile and that growing out half way between adjacent ditches.

During a heavy rain storm this water table is raised temporarily. The water which is in the soil lieing immediately over the tile reaches them quicker than does that from a short distance to either side, and still quicker than does that from some distance away. Then after the rain has ceased, this temporarily raised water table again lowers gradually until it again reaches the location of the permanent table. The speed with which it is lowered after a rain will depend upon the tightness of the soil, being more slow in a tight soil than in a mellow, open soil.



Showing action of water table. 1. Location at end of rainstorm. 2. Location one or two days later. 3. Lowest level of table.

CHAPTER X.

Location Of Drains

Wherever possible, mains and submains should be laid along the natural courses thru which the surface water drains. These generally give the best grade which is available under the existing field conditions. At the same time they generally place the mains in the best location from the standpoint of connecting the laterals into them.

This however does not mean that a main ditch should follow all the meanderings of these natural water courses which wander all over a low, level hollow in reaching their destination. They should reach their destination by the most direct routes possible. Still, they must make whatever bends and turns are necessary to permit the connection of other ditches into them without having to carry these ditches across or thru ridges or wide low spots.

Remember that a short ditch which runs direct to its destination will have a steeper fall or grade than if it had gone a round-about way to reach the same destination. And it is important to lay all lines of tile so as to give them the most fall possible. This fall or grade of a ditch has a great deal to do in determining the amount of water which will run thru it in an hour or a day.

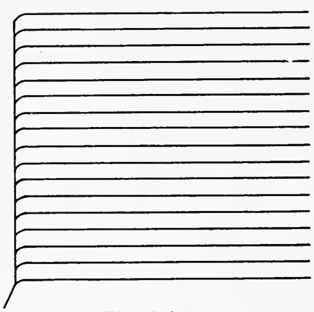
In level ground, lay the laterals in long parallel lines with as few submains as possible. This allows the area to be drained with the fewest rods of ditch possible.

If a hill or hill-side slopes in only one direction, then lay the laterals down this slope. This gives them the maximum amount of grade and so keeps them free of silt. The steeper the grade, the swifter the current in the ditch. The swifter the current in a ditch, the less sediment will be deposited in it.

If the hill side slopes in two directions, lay the laterals along the longest slope. This longer slope is generally parallel with the surface water channel at the foot of the slope. The laterals laid in this same direction will intercept the water as it works its way down the face of the hill side and keep it from working its way to the surface.

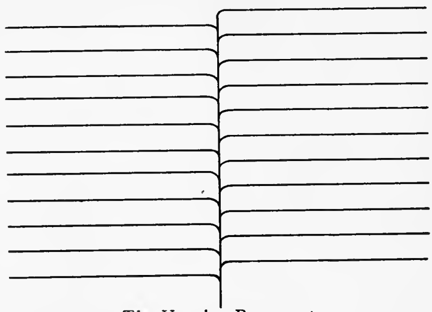
In the case of springy spots, locate the laterals so as to intercept the subsurface water before it has had time to rise to the surface, or into the surface layer of soil. This is much better than merely carrying it away after it has risen.

Of course no hide-bound rules can be laid down to govern every man in the location of all the ditches on his farm. Conditions and problems on your farm will probably be more or less different from those on the farm of a neighbor, or a man in another county or state. These individual conditions on your farm must, of necessity, determine the methods to be used. But a knowledge of the general principles to be observed in solving problems of different kinds will be of much value to you in planning your system so as to give the largest possible efficiency.



The Gridiron system.

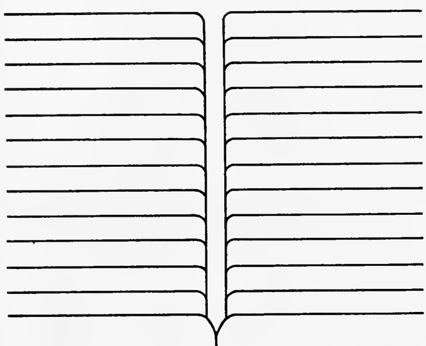
Laterals on level land In broad, level areas, where several lines of laterals are needed to carry off the water properly, you are given a chance to choose between the two principal methods of arranging laterals, described as follows: The "Herring Bone" system is so named because of its resemblance to the backbone and the ribs of a smoked herring. A main ditch runs thru the middle of the area. The area on both sides of this main is drained by a series of parallel laterals which run practically perpendicular to this main ditch. Notice that a lateral on one side of the main enters at a point midway between the entrance to it of two laterals on the other side. This is so that two streams of water will not enter the same point of the main from opposite sides of it. Two streams entering from opposite sides in this way would clog and interfere with the flow of water thru the main much more than is done where only one stream enters it at a given point.



The Herring Bone system.

The "Grid Iron" system is so named because of its resemblance to the grid iron or the broiling iron of the kitchen. It consists of a main ditch running across the lower end of the wet area with one set of parallel laterals running into it. This is one of the most efficient systems possible for tiling level areas. It requires a smaller total length of ditches to tile a given area than does the Herring Bone system of grouping, for these reasons:

In ordinary soils these mains will thoroly drain all ground for a distance of about fifty feet on each side. That portion of each lateral passing thru this area drained by the main is wasted so far as concerns the drainage of the ground thru which it is passing. The only duty it performs is to conduct the water collected by the upper portions of the lateral to the main ditch furnishing the outlet for it. Thus, where the lateral is laid perpendicular to the main into which it empties, the last fifty feet of it is wasted so far as concerns the work of collecting water from the soil. The Herring Bone system thus wastes just



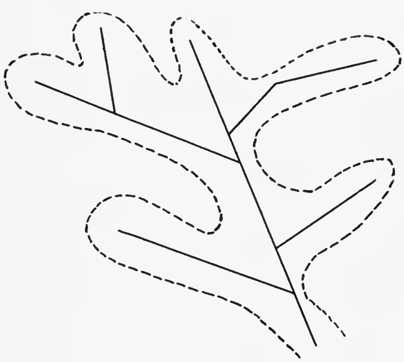
THE DOUBLE MAIN SYSTEM

twice as much of its laterals as does the Grid Iron system draining the same area.

Laterals on rolling land Sometimes there will be found wide sloughs where the slope of the side hills requires that the laterals should be laid more or less perpendicular to the bottom of the slough. This condition naturally suggests the use of the Herring Bone method of grouping, rather than the Grid Iron method. But the saving feature of the Grid Iron system may be had by using a combination of the two, known as the "Double Main" system. Parallel mains are run thru the slough at the foot of the two slopes. Thus the laterals from each hill side feed into their own main on the Grid Iron system. The complete system has the general appearance of the Herring Bone system, but also has the ditch economy of the Grid Iron.

These mains should be placed at, or just above, the foot of the slopes. Placed here, they catch all the seepage flowing along the layer of tight subsoil in the hillside before it has had a chance to get out into the more level bottom between the two slopes. If the bottom is underlaid by a layer of porous soil charged with water under pressure, these mains at the foot of the slopes should be set deep enough to penetrate into this and remove this water before it has worked its way out under the bottom land. Care should also be taken to make them large enough to carry away this added supply of water. If placing them at the foot of the slopes makes them too far apart to drain all the ground lieing in between them, then the necessary number of laterals should be placed between and parallel to them to drain this area. These laterals will be joined into the mains at the foot of the slough.

Often in rolling land the bulk of the tile are laid in only wet draws and depressions located between adjacent high spots, hills or ridges. Here the contour of the ground—the slopes and their arrangement with reference to each other—will govern the location and arrangement of laterals to a considerable extent. Such an arrangement is known as the "Natural" system because the arrangement is determined by the nature of the ground. In such a system there is not much choice left in planning the location and arrangements of the laterals and their mains.



The "Natural" system.

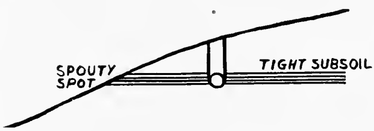
Spouty spots in level land The cause of spouty or springy spots in level land already has been explained. A good way in which to correct such a condition, where the damaged area is not too large, is to dig a well down into the center of the damaged area until it has gone some little distance into the porous

layer of soil lieing between the two tight layers. Fill the well with broken tile or rock and coarse gravel to a point just below the bottom of the plow furrow. Lay a line of tile from this well along the surface of the upper impervious layer to conduct the water from it to a main or outlet. The water rises more easily thru this well than thru the crawfish and other holes, and is carried away by the tile before it has a chance to saturate the more porous layer of surface soil.

Wells and connecting ditch for draining spouty spots in level land.

Sometimes there will be found a considerable area of this sort of low spouty land. If careful investigation or prospecting shows that the condition cannot be cured by a deep laid ditch at the foot of the slope on both sides of it, then a complete system of ditches or laterals should be laid thru it. These should be laid deep enough to penetrate to below the top layer of impervious earth to a depth of a foot or more. These will intercept the subsoil water which is rising under the pressure and carry it away before it can rise into the surface soil.

Spouty spots on hill sides The cause of these spouty spots on hill sides has been explained in previous paragraphs. The way to cure them is to go back up the side of the hill to some point high enough so that the tile laid there will be from one to two feet below the level of the wet spot. Here dig a ditch along the face of the hill instead of down the slope of it. Have it reach to some distance to either side of the spouty spot and then connect it into the main or the outlet. Where a series of these spouty spots is found, or there is a continuous line of springy ground along the face of the hill, run a drain the full length of the slope.



Location of tile for draining spouty spots on hillside.

In this way the surplus water from the soil above the spouty place is caught and carried away by the tile. It does not have to work its way slowly along thru the subsoil until the tight layer outcrops on the side of the hill. This is far better than to simply run a tile from the outlet or main up into the spouty spot and carry the water away after it has come to the surface. It is much better to prevent the ground from getting wet than it is to cure it after it gets wet.

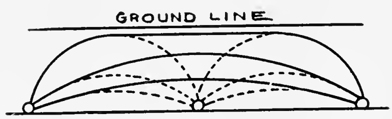
CHAPTER XI.

Distance Between Laterals

The distance which laterals should be placed apart is dependent upon the following factors: (1) The tightness of the soil above the tile. (2) The amount of the rainfall; what percentage of this annual rainfall comes during the growing season, and how much will fall in the worst storms, or within a few days at a time. (3) The levelness of the surface, and so what percentage of the rainfall enters the soil or runs off as surface drainage. (4) In the case of low spots with no surface outlet. Here it depends on the area of the water shed which sheds its water onto this area. Since there is no surface outlet for such an area, all water falling or running onto it must be carried away by the tile. (5) Whether or not subsurface water under pressure must be carried away in addition to the rain water which falls directly on the surface above the tile. (6) The depth to which the tile are laid.

Tightness of the soil Suppose that your farm is level, so that little or no surface drainage is available. The rain water which falls onto it can escape only by evaporation, or by descending thru the soil. Suppose again that the surface soil is mellow and loose, but has a tight subsoil beneath it. This tight subsoil holds the water imprisoned in the mellow surface soil above it. The surplus water can descend freely thru the mellow soil until it strikes this tight layer of subsoil beneath it. Also the water can move along the surface of this tight subsoil freely. When the tile are laid in this soil, the water can reach it freely and quickly. The water from a considerable area on each side of a line of tile is able to work its way to the tile in the safe limit of time in which it must be removed from the soil to avoid damage being done. In such a soil the laterals may be placed a considerable distance apart, depending further upon the other conditions which have been mentioned. Cases are some times found under such circumstances where laterals will work well placed as much as 150 or even 200 feet apart.

But it is different where this layer of soil above the lines of tile is also tight. In the tight clays, the water moves slowly in both the down ward and the horizontal direction. In the tight clay soils it will take as much as three or four times, as long, or even longer, for water to travel a certain distance as it would take to travel the same distance thru a mellow sandy loam soil. Under such circumstances laterals should be only one third to one fourth as far apart as is the mellow, sandy loam soils.



Showing the effect which distance between laterals has on depth of water table at different times following a rain.

This means that there are conditions in tight clay soils where the laterals should not be more than 50 to 75 feet apart.

But not all clay soils and subsoils are this tight.

We have those grades variously known as joint clays and sandy clays. The water moves thru them more freely and more rapidly than it does thru the tight clays, but not so rapidly as thru the sandy loams. In such open clays the laterals may be as much as 100 feet apart and still the tile will work satisfactorily.

It is seldom that only one kind of soil or subsoil will be found on one quarter section farm. It more often happens that there are three or four different kinds or conditions found. Each of these presents its own problem, and demands its own distance apart of laterals, in order that they may do their work properly and still the system be installed as economically as possible.

Amount of rainfall In regions of heavy rainfall there is more surplus water to be removed from the soil than there is in regions of less rainfall. This demands that the tile be placed closer together, all other things being equal.

You must also consider what seasons of the year the bulk of this rain falls on your land. In some regions of comparatively light rainfall the bulk of it is concentrated into a rather short part of the spring season. In such cases the tax on the soil and on the tile is as great during this crucial time of the year as it is in another region where the total annual fall is greater, but where its fall is distributed more uniformly thruout the year.

The possibility of very heavy storms also effects this problem. For instance, here in the upper Mississippi valley we can count on a very wet spell at least once during the spring and once again during the summer. You should lay your tile so as to protect your farm against these wettest and worst times, rather than against the average times and conditions.

The levelness of the surface Where the surface of the soil has very much of a slope, a considerable portion of a heavy rain will run off it without having entered the soil. The percentage or amount of this runoff will also depend on the mellowness of the soil and the ease with which the water soaks into it. Where the surface of the field is level, little or none of even the heavy rains runs off. This throws upon the tile, the entire load of removing the surplus. So, the more level the ground, the closer together the tile should be.

In comparatively level country it is not uncommon to find low spots without a surface outlet. These are shaped much like a broad level dish. On all sides of them will be found higher ground with a certain amount of slope from which more or less surface water drains into this low spot. This surface water must be admitted direct to the tile by means of a surface inlet, or else must work its way thru the soil to the tile.

Surface inlets give the best results as they act quickly. But they are not satisfactory on a rented farm where a new tenant takes pos-

session every year or two. How to construct these is explained in a later chapter of this book.

Where this surface water is left to work its way to the tile thru the soil it increases the amount of water which must flow thru the tile laid in this area. This demands that the laterals be placed closer together than otherwise would be necessary. In some cases of this kind it is found necessary to place them only fifty feet apart when one hundred feet would be satisfactory if it were not for the surface water.

Cases are encountered where the principal amount of water reaching the tile comes from the subsoil under pressure instead of from the surface. Sometimes the surface soil conditions alone are such that the laterals can be placed 100 feet apart. And yet the amount of subsurface water coming up under pressure is so great that they must be placed as close together as 50 feet in order to handle all the water coming from these two sources.

The depth of the tile It is a combination of their distance apart and the depth of the tile which determines the depth of the permanent water table at its highest point half way between two adjacent lines of tile. When two adjacent laterals are 4 feet deep and 100 feet apart, the highest point of the water table will be nearer the surface than when they are 4 feet deep and only 50 feet apart. General experience of drainage engineers seems to indicate that where two adjacent laterals are 100 feet apart and 4 feet deep the highest point of the water table will be practically the same as where the tile are three and a half feet deep and fifty feet apart.

It does no good to go below hard pan in an effort to lower the water table. The hard pan itself becomes the table, so it is a waste of labor to go deeper for that purpose. When a hard pan is encountered near the surface, the depth of the water table will have to be regulated by distance apart more than by depth of the ditches.

CHAPTER XII.

How Deep To Lay Tile

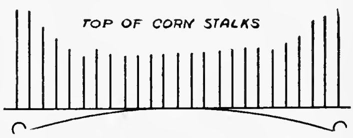
Depth of water table For our ordinary crops this water table should be at least three feet below the surface of the ground at a point midway between any two adjacent lines of tile. A low water table can be secured much cheaper by laying the laterals deep than by laying them close together. Take the case of 4 feet deep and 100 feet apart as compared to three and a half feet deep and 50 feet apart, based on the ruling prices of 1917 for digging and for five inch tile. At these prices, five inch tile laid 4 feet deep cost $1.27 a rod; tile laid three and a half feet deep cost $1.15 a rod. So that where the ditches are placed three and a half feet deep and fifty feet apart, the cost of getting a low water table is $2.30 as compared with $1.27 for the same area with the tile laid four feet deep and one hundred feet apart. Where they are three and one half feet deep and seventy five feet apart the cost is $1.75 as compared to the $1.27 for four feet deep and one hundred feet apart.

Water supply To meet the demands of our crops, especially of corn, there not only must be a large amount of capillary water in each cubic foot of the soil, but there must also be many cubic feet of soil so charged with water for the plant roots to penetrate in their search for food and water. The supply of this capillary water is restored each time it rains. A deep layer of soil above the water table will retain more of the rain fall in the form of capillary water than will a shallow layer resulting from a high water table. And the tile must be deep in order to give this deep storage basin for capillary water.

During a dry season there will be more moisture stored in the deep soil by the air percolating thru it than in a shallower soil. As the air works its way downward thru the soil it reaches a cooler temperature every few inches. Finally it reaches a temperature where it cannot hold its moisture, but must give some of it up and deposit it in the form of capillary water on the particles of soil surrounding it.

As it goes still deeper, it gets still cooler and deposits still more of its moisture. In a very shallow soil it may not reach a temperature low enough to make it give up any of its moisture. Thus it is seen that where the water table is deep more water is extracted from the soil air than where it is nearer the surface. Deep laid tile will thus protect a crop against drought better than will shallow laid tile.

Heat supply Where the water table is low, there is a great deal more heat stored up than where the water table is nearer the surface. Crops growing above a deep wa-



How shallow tile affect the growth of corn.

ter table actually have a longer effective growing season than have those growing above a shallow water table in the same location.

In Cerro Gordo County, Iowa, there was found a few years ago, a field in which tile had been laid some ten to fifteen years before, but had been laid to a depth of only two, to two and a half feet. This year in question was a cold, wet one. A careful examination was made to determine their effect on the crop. Where the tile were only two feet deep they had no appreciable beneficial effect on the crop, even where the corn hills were immediately over the tile. Where they were two and a half feet deep the corn hills immediately over the tile were a little higher than those in the rest of the field. But those a few feet away showed no benefit from the tile. With the exception of these comparatively few hills, the entire field was a very poor crop of corn; it was small, yellow, sickly and scrawny looking.

Not far away was another field of corn on land where the tile had been laid three and a half to four feet deep, but had not been laid as many years as had this more shallow system. Here the corn crop was in far better shape than in the other field. In fact it was as good as there was to be found anywhere in the county that year. The deeper tiled field was warmer than was the shallow tiled field as there was a deeper layer of soil above the water table in which the heat from the sun was stored.

Frost level With many men the chief argument for putting tile deeper than three feet, which has any force, is to get them down below frost level. Four feet will not do this in the latitude of nothern Iowa, or for some considerable distance south of here. In severe winters, with little snow on the ground, frost has been known to go as deep as six feet here. So protection from frost is not a valid argument for putting the tile down to four feet—but getting a deep water table surely is, and should be enough argument to convince any man.

You need not be worried about your tile in the ground being damaged by freezing, if the tile is well made. Tile which is made of properly mixed shale, and which has been burned hard so it will not absorb a great deal of water into its walls, will not be damaged by freezing when in its ditch even tho it may be damaged some by freezing when wet and exposed to the air either by lying on top of the ground or being exposed at an outlet of a ditch. Inspection of tile laid twenty years ago, shows that if you will use a well mixed, hard burned shale tile of a brownish tint or color you need not ever worry about their being damaged by frost when it reaches them in an extremely cold winter.

Muck or peat Soils Muck or peat soils shrink after they are thoroly tiled out. This shrinkage is a rather slow process, it requiring two to three years to get a muck or peat soil well settled. The amount of this shrinkage depends upon the depth of the layer of muck, and upon the percentage of partially decomposed vegetable matter contained in it.

Tile should be laid in this sort of soil deep enough so that after this shrinkage has been completed they will still be as deep as those laid in other soil. A good example of how to handle this sort of soil is found in the method used by one of the largest land owners in northern Iowa, a man who has handled successfully a number of farms in which peaty soils predominate.

This man lays his tile in this sort of soil four and a half to five feet deep. The drains are laid about 200 feet apart, as at this distance they draw well in unsettled muck or peat soils. He pastures this land for two or three years. During this time this soil is not very good for growing crops, but will produce very fair pasture. The grazing of the cattle helps to pack the soil and so hastens its shrinkage and settling.

By the time the muck is well settled, the tile are not drawing well. So now he puts laterals in between the first ones so they are now only 100 feet apart. He lays these new ditches to the same depth the old laterals now are; this is about four feet. In this way he saves this last six inches to one foot of digging on this last half of the laterals. The land is now ready for cropping, and the tile are all laid to a good depth. Had the first tile been laid only four feet deep, none of the ditches would be more than three to three and a half below the surface of the field and the land would not be well drained with the ditches this depth and this distance apart.

Water under pressure Where the tight layer of subsoil is underlaid by a layer of soil containing water under pressure, tile laid in the top layer of porous soil often will not do a good job of draining the land. In such cases a series of deep laid laterals is about the only solution of the problem. A good illustration of this is found in the case of a tract of land formerly owned by the late Mr. Denison, the founder of the Mason City Brick & Tile Company.

This tract of land laid in what is called an old pre-glacial stream bed. It was a broad, low, level area of peaty or muck soil with very inferior surface drainage. Furthermore, it was what is commonly known as craw fish land. Underneath the layer of peaty soil was a layer of very tight clay soil or hard pan. This layer of hard pan was underlaid in turn by a layer of water bearing soil. This water was under pressure resulting from the weight of the water which seeped into it on the slopes of the higher ground where it was not covered by this layer of hard pan which covered it underneath the peat. The craw fish bored their holes down thru this layer of hard pan in search of the permanent supply of water. These craw fish holes furnished sufficient outlet to permit the water to rise from the water bearing layer beneath in such quantity as to keep this place a veritable swamp of peat or muck.

How to place tile when subsoil water is held under pressure.

Some common every day, "spade and shovel" tilers had put a system of tiles into this tract. They thought it was not necessary and would be too much work and too costly, to go into or thru this layer of hard pan. So they simply

laid the tile down to it, thinking the water all came from the rain which fell on the area being drained. But the condition was not relieved by this system of ditches.

Mr. Denison secured the services of a capable and experienced drainage engineer when he purchased the tract, and gave him instructions to do a thoro job of tiling it. A careful inspection of the tract, noticing the craw fish holes and digging inspection holes down thru the hard pan, convinced the engineer of the presence of water under pressure. He found that the hard pan was underlaid by a layer of fine sand from which water rose rather slowly into the holes he dug into it.

He decided that a series of wells sunk into this layer and connected above the hard pan by the lines of tile already laid would not solve the problem because the sand beneath was so fine the water would not move sideways readily enough, but would continue to rise thru the craw fish holes and be soaked up by the sponge-like peaty soil above. So all the tile were laid deep enough to carry them down thru the hard pan and some little distance into the water bearing layer beneath it. In other words, the tile were so laid that they drained this lower water bearing layer just as an ordinary system of laterals drains the soil in which they are laid.

This solved the problem completely. Ever since that time this tract has been thoroly drained. There has been no more trouble from surplus water. The land can be worked at any time of the year, even when higher but less well drained land cannot be worked at all. It is true that it was necessary to put the tile six to seven feet deep. But by doing so a worthless piece of bog land was made into as fine land as can be found anywhere. And yet, placing the tile to an ordinary depth did not do this.

CHAPTER XIII.

What Sizes Of Tile To Use

The tile used for both laterals and main ditches should be large enough to carry away the water as fast as it is delivered to the ditches. The great bulk of the soil which needs tiling is some form of clay or clay loam, or a mixture of the two. There is no danger of removing the water from these soils too rapidly. There is much danger of not removing it rapidly enough. So the ideal to work toward, in planning a system of ditches, is one which will carry away the water just as fast as it gets to the laterals.

How diameter effects capacity The amount of water which will flow thru a given ditch within a given time depends, among other things, upon the cross sectional area of the tile. The area of the cross section varies as the square of the diameter—the product obtained by multiplying the diameter by itself. Let us illustrate this fact thus: The square of 4 is 16; the square of 5 is 25. So that a five inch tile has a capacity 1-9/16 times as great as has a four inch tile.

The actual working capacity of a line of tile is not as great as the capacity of a single tile, or an iron pipe, of the same diameter. This reduction in capacity is caused by irregularities in joining the ends of two adjacent tile; by crooks or twists in the ditch, by irregularities in the grade or slope—that is, by high spots or low spots in the bottom of the ditch. These irregularities tend to "stricture" the ditch, or to reduce its active cross sectional area. An irregularity will have a more serious effect on a small tile, than on a larger one. A half inch "jog" in making a joint will destroy a larger percentage of the capacity of a four inch tile than of a five inch.

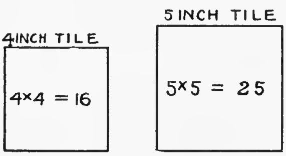


Diagram to show how the diameter of a tile affects its capacity.

How grades effect capacity The amount of water discharged from a tile ditch will depend directly upon the speed or velocity with which a stream flows. A ten inch tile flowing full, with a velocity of two miles an hour, will discharge just twice as much water as will another ten inch tile, running full, at a speed of only one mile an hour. The one with a speed of two miles an hour will furnish a satisfactory outlet for just twice as many acres of wet land as will the one with a speed of only one mile an hour.

In any case the grade of a ditch should be steep enough so that the current of water flowing thru the tile will be strong enough to carry with it all the silt and sediment which gets into the ditch, rather than depositing it. The capacity of running water to carry solid matter varies directly as the sixth power of the velocity of the current. This means that a stream with a velocity of two miles an

hour will carry pieces of earth weighing sixty four times as much (2x2x2x2x2x2=64) as those which will be carried by a stream with a velocity of only one mile an hour.

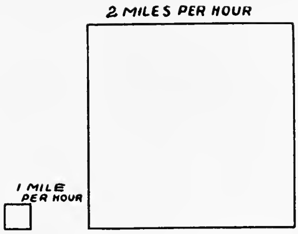


Diagram to show how doubling the rate of flow of water affects its capacity to carry silt.

Now notice how that rule works: Suppose you were laying a ditch with such a grade that it gives a stream velocity of two miles an hour. Then you came to a place where you had to dig deep for a ways to maintain that grade, or else go to a grade which would give a velocity of only one mile an hour, and you chose the latter solution. When the water flowing thru the tile came to that more gradual grade, its velocity would be changed from two miles an hour to one mile an hour, and its ability to carry sediment would be reduced to only one sixty-fourth of what it was before; it would have to drop onto the bottom of the ditch all particles of soil which weighed any more than one sixty-fourth as much as did the largest pieces which it was able to carry before at the higher grade. In a short time this would badly choke the ditch at this point.

A low spot, or a high spot, in the bottom of a ditch acts the same as a change of grade and slows down the velocity of the stream of water flowing thru that portion of the tile—except when the tile is running full and with the water under pressure from having the soil above it saturated with water. So that when the stream comes to one of these high spots, or low spots, it slows down and deposits the larger particles of soil which it may be carrying.

Thus you will see the importance of laying all ditches with as good grade as possible, and of keeping this grade as constant or uniform as you can. Tile laid to a good uniform steep grade will keep free of silt and always have maximum efficiency. Tile laid with a slight fall, or with cracks and humps in it, will be apt to fill up in spots and reduce the carrying capacity and the draining efficiency of all that portion of the ditch lying above this spot.

Whenever possible, lateral ditches should have a fall of at least .3 foot in the hundred, or practically the same as three and five eighths inches to the hundred feet. Of course there are often cases in a very level country where this much fall cannot be had without laying the lower ends of the mains and laterals very deep. Where the depth necessary to give this fall is so great as to make the cost prohibitively high, you will have to lay the laterals with less grade. They will work at less grade, but they will not work as fast and they will not drain so wide an area when the ground is saturated with water, unless you correspondingly increase their size.

Main ditches should have all the grade that is available so as to reduce as much as is possible the size of the tile necessary to carry away the water brought to the main by the laterals feeding into it. Large ditches soon run into a lot of money. So it pays to keep them as small as you can and still have them do their work properly. But when necessary, mains can be run perfectly level and still work; but of course their size will have to be increased so as to give the required

capacity. In a wet spell, when the ground is saturated with water, and when the laterals and the submains are running full, the water in this main will be under pressure from this upper water and so will have a reasonably satisfactory velocity. Its velocity will be greatest when it is needed most.

Best size for laterals It is a mistake to use tile smaller than five inches in diameter for laterals. Some men may say that it is just throwing good money away to put in anything larger than three inch tile for laterals. On the contrary, it is throwing away good money to use anything smaller than five inch tile for laterals.

And here are some mighty good reasons for that statement:

The cost of digging the ditch for the three inch tile is just the same as the ditch for five inch tile. In fact all items of labor are the same, except the cost of delivering the tile from the town to the ditch. The labor cost of a job of tiling is more than the cost of the tile. Most manufacturers charge the same for threes and fours as they charge for fives. Those who do sell cheaper make only a slight reduction for the threes and fours—nothing to compare to the difference in water carrying capacity of the different sizes. So but very little, if anything at all, is gained in this matter of cost by using the smaller sizes.

The water carrying capacity of the five inch tile is more than one and a half times as great as that of a four inch tile, it is more than two and two thirds times that of a three inch tile. A half inch lap in a joint, or a half inch variation from accurate grade, will not make as great a proportional reduction in the capacity of the five inch tile as it will in that of the four or a three inch one. So that the five inch tile will always work much nearer its maximum possible efficiency than will the smaller sizes of tile.

Five inch tile will remove the accumulated water faster than will the smaller sizes, and so will do a better job and will drain a wider area in a given time. After a system has been in for some time, the soil becomes more porous and open so that the soil water reaches it more rapidly. In a very wet season, when there is a great deal of rainfall within a few days, the water will reach the tile more rapidly than in a less open soil. In a very tight soil the smaller sizes of tile may handle all the water which reaches them for the first two or three seasons. But in time they will be drawing from such a wide area they are not able to handle the water as rapidly as it reaches them. You should lay your laterals so as to care for the needs of the future as well as those of the present. This means you should use five inch tile for the laterals.

Best sizes for mains The proper size of tile to use for main and submain ditches will depend on the following factors: (1) The area drained. (2) The levelness of that area. (3) The area of higher ground from which surface water runs off onto this area, and what percentage of the rainfall runs off as surface water. (4) The texture of the soil which is being drained. (5) To what extent surface intakes are to be used to admit surface water direct

to the tile. (6) The grade on which mains and submains are to be laid. (7) What amount of rainfall is to be drained away in twenty-four hours.

These factors are all so intricately related that you should consult an experienced and competent drainage engineer to help you decide what sizes of tile to use for these mains and submains, as well as their location and the location of the laterals. Only a man who is thoroly informed on the scientific principles involved in farm drainage is capable of deciding these problems in such a way as to give you a thoroly efficient system of tile.

When tile are laid four feet deep, and have been in long enough for the soil to be well opened up, the mains need to remove rainfall only at the rate of one quarter inch of rainfall per twenty-four hours. Under such soil conditions any water standing on top of the ground, as a result of its falling faster than it can be soaked up or run off, will soak into the ground within a few hours so that the surface will be in condition to be plowed or cultivated within six to twenty-four hours after a heavy rain. One inch of rainfall will saturate about four to six inches of normally moist soil which is good and porous. So it would require eight to twelve inches of rainfall, falling just as fast as the ground will soak it up, to saturate the four feet of ground lying above the laterals. This is a condition which never occurs in this country. So this rate of removing the surplus water from the soil is fast enough to meet all the conditions which are imposed on our soils, and still prevent damage to crops.

The various sizes of tile shown in the accompanying table will carry away the water delivered to them from the soil by the laterals at this rate for the number of acres shown, providing the main of this size is not over 1,000 feet long. If all the surface water is to be removed also, instead of letting it run over the land, the title will have to be considerably larger.

TABLE SHOWING AREAS DRAINED BY TILE MAINS LAID UPON THE GRADES INDICATED

Computed by formula recommended by C. G. Elliott, formerly Chief Drainage Investigations, U. S. Dept. of Agriculture

Grade per 100 feet in Decimals of a foot with approximate equivalents in Inches.

Diameter of Tile in Inches	0.04 ½ in.	0.05 ⅝ in.	0.08 1 in.	0.10 1 8/16 in.	0.12 1½ in.	0.16 2 in.	0 20 2⅜ in.	0.25 3 in.	0.30 3⅝ in.	0.40 4¾ in.	0.50 6 in.	0.75 9 in.
	Acres of Land Drained											
5	17.3	17.7	19.1	19.8	20.6	22.1	23.5	25.1	26.7	29.5	32.0	37.7
6	27.3	28.0	29.9	31.2	32.5	34.8	37.0	39.6	42.0	46.4	50.5	59.4
7	39.9	41.1	44.1	45.9	47.7	51.1	54.3	58.0	61.6	68.2	74.0	87.1
8	55.7	57.3	61.4	64.0	66.5	71.2	75.6	80.9	85.8	95.0	103.3	121.4
9	74.7	76.5	82.2	85.6	89.1	95.3	101.4	108.4	114.9	127.0	138.1	162.6
10	96.9	99.5	106.7	111.2	115.6	123.9	131.6	140.6	149.3	165.2	179.2	211.1
12	152.2	156.1	167.7	174.8	181.7	194.6	206.8	221.1	234.5	259.2	281.8	331.8

Let us see now, how this table works, by using some examples as follows:

Suppose that you have a farm of 160 acres, all of which is so level that it requires tile laid every hundred feet. Suppose also that this farm lies high enough so that surface water does not drain down onto it from any land higher up. Suppose also that your main runs thru such a level section that there is a natural fall of only 1½ inch to the hundred feet. By consulting this table we find that a ten inch main laid at this grade will drain only 115.6 acres at the rate of one fourth inch rainfall in twenty-four hours; while a twelve inch tile will drain 181.7 acres under the same conditions. Manufacturers do not build eleven inch tile, so you should use the twelve inch. The slight added expense involved will be far more than compensated for by the greater efficiency of your system than if you had used only the ten inch main.

Suppose a second time that your farm of 160 acres had only forty acres of wet ground with the same fall for an outlet. Suppose that this forty acres had this same slight fall to its surface, and that the other 120 acres surrounded it and did not need drainage because a goodly percentage of the rainfall ran off as surface water onto this wet forty. In figuring what size main to use, you would have to count in a portion of this higher land. You would have to use a main large enough for anywhere from eighty to 120 acres, depending on the percentage of the rainfall on the high land which reached the low land as surface runoff. You see, with this very gradual slope to your low land, not all the water which reached it as surface run off from the higher land would leave it as surface run off. Some of it would soak into the soil of this lowland and reach its tile as the only chance of escape. This would make the demands placed on the main greater than that originating solely from the rain which fell onto the low land.

Suppose a third time, that this wet forty acres was a pond, without outlet. All the rain which falls onto it would have to escape thru the tile. All the run off from the higher land would also have to escape thru these tile. If these slopes of the higher land were very steep, much more of the rainfall would reach the tile from the entire 160 acres than would if the land were all level, because only a small portion of it would be taken up by the high land as capillary water. This would make the demands on the tile much greater than if all the land were level and needed tiling. In extreme cases of this nature you might have to use a tile large enough to care for as much as 240 or even 300 acres of normally level land such as is contemplated by this table. It matters not whether this accumulation of surface water soaks its way thru the soil into the tile, or is admitted direct by means of surface intakes, the tile will have to be this size to remove it fast enough to prevent the crops growing on this low land from being damaged by water standing in or on the surface of the soil.

CHAPTER XIV.

Some Very Important Points

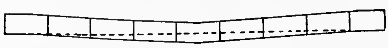
When tiling do a good job When a job of tiling is done right, there is no investment which can be made on any farm which will pay larger returns. If not done right, the investment will not repay as large returns as it should. The difference between a good job of tiling and a poor one is so great that you cannot afford to take chances that it will not be done right.

To insure that it is done right, you should employ an experienced and capable drainage engineer. The fee which must be paid for his services is so small when you consider the importance to you of having the job done right that you should not haggle for a moment over the size of that fee. The important thing to you is, not the amount he is going to charge you, but whether or not he knows his business and whether or not he attends to it.

Have him assist you in deciding where to locate the ditches. Have him make a survey of the entire water shed which drains surface water onto the land to be tiled. Have him make a survey of each ditch, establishing grades and sizes of tile for each. Have him make a map of the entire system, including the length of ditch for each size of tile and a profile showing the grades or slopes for each ditch. Have this map "tied into" some permanent and official monument such as a section or township corner. Keep that map carefully for future reference in case it ever becomes necessary to examine any part of any ditch, or you ever want to add to the system of ditches. Have your engineer inspect all tile with an instrument at frequent intervals along the ditch before they are covered more than mere blinding.

Never let a ditcher lay a single rod of tile "by water grade" or by guess. No tile ditch ever laid, "sucks like a chimney." A tile ditch will not work like a siphon, no matter how hard some "Round Head" may argue that it will. Make him do his work according to the instructions of your engineer. Keep close watch of him to see that he does it that way. Do not trust any digger. While a digger may be perfectly honest, yet it is your land instead of his in which he is doing the work.

Put in a system of tile which will make your fields dry and productive under the worst weather conditions which exist in your section of the country. Do not tile to meet average conditions. It is the worst years, not the average ones, that wet fields make the biggest holes in your bank account. If you tile to meet the worst conditions in your section of the country, your



The effect when the digger does not follow the engineer's grades properly. The tile below the dotted line fill up with silt and reduce the draining ability or capacity of all the ditch above it.

system of tile will pay for itself much quicker than if you had tiled to meet only average conditions. And it will pay you an additional profit much quicker, and continue to pay these larger profits a longer time.

You take out life and fire insurance to meet the worst crisis possible, not to meet the average conditions. The same principle should be followed in tiling your farm. You should tile to meet worst conditions, not average ones.

Plan your system carefully Sometimes a man does not have enough money available to cover the cost of a complete system of tiling. At the least, the average man is unable to tell how much a good job is going to cost him. Naturally, he wants to have a fairly close estimate on this before he makes any definite move. In such a case, get your drainage engineer to come out and go over the proposition with you. Tell him that you want to know approximately how much it is going to cost to put in every rod of tile which your farm needs. It will not take him very long to make you a very close estimate.

If you have the money, do the entire job. If you do not have quite enough, your banker will be more than glad to loan it to you. Bankers are so thoroly convinced of the value of tiling wet land that some of them are even lending money for that purpose with only a second mortgage, or even simply a personal note, as security. Remember that the increased yields the first year will far more than pay interest on the first cost. There are many instances in every county where this first year's increased production has repaid the entire cost of tiling.

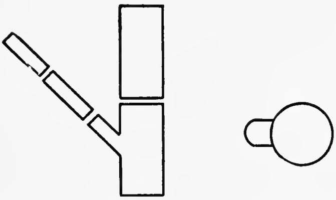
If you do not have enough money, and do not want to borrow, there arises the question of which of two things to do. Shall you spread your available cash over the entire farm, doing only as good a job as you can with the money? Or shall you use it all in doing a thoro job over as many acres as the money will cover?

Here is the thing to do in a case like that. Pick out the very wettest part of the farm, the part which is now producing you the least. Spend your available money in tiling that part of it thoroly. Do not skimp any part of it in an attempt to make your money cover a large acreage. That is a waste of money. Forty acres of wet land thoroly tiled will give you a larger return on its cost than you would get if you had spent the same amount of money in doing only a fairly good job on sixty or eighty acres of the same kind of land. Then the next year, take the extra money you have earned from this tract you have tiled this year and spend it tiling just as much land as it will do a good job on. Continue each year, using the extra money you earn from the tiled land, with which to do a thoro job on more land. In a very short time you will have the entire place tiled. The original outlay for tiling will be only what you spent for the first job.

Of course, the larger the area on which you can do a good job the first year, the quicker you will get it all tiled and the quicker the original cost will be paid back to you in the form of increased profits from the farm. If you have enough money with which to tile an eighty out of a quarter section the first year, you will make more

money in the next five or ten years if you will start out with the eighty than you would if you had started out with only forty acres, planning to make a forty pay for tiling the rest of the farm.

Connecting ditches One ditch should not enter another perpendicularly. Connections should always be made at an angle of about forty-five degrees, or one half of the perpendicular. The stream of water flowing into a main from a lateral naturally tends to stop or interfere with the stream flowing thru the main. If the lateral enters perpendicularly, it will interfere with the flow of the water thru the main a great deal more than it would if it had entered at an angle of forty-five degrees. This interference is just the same as reducing the size of the main just that much. A main with its laterals and submains entering it perpendicularly will not drain properly as many acres as it would if they had entered at an angle of forty-five degrees.



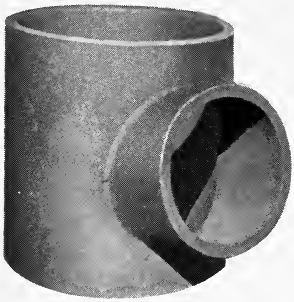
The proper way to connect one ditch to another.

If your laterals are laid out on the grid iron principle, and are perpendicular to the main, the last fifteen to twenty five feet of the laterals should be bent into a curve so that they finally enter the main on a slant. This bend should not be made in the form of an abrupt angle, but should be made in the form of a part of a circle.

The lateral ditch should be connected into the middle of the main tile. It should not be made into the bottom of the main, or into the top of it.

The main ditch should be deeper than the laterals. Enough deeper so that the curved portion of the lateral will have more fall than the rest of it. This increased fall will tend to increase the velocity of the stream from the lateral to compensate for the tendency of this curve to slow it down, or may even increase it slightly. This will throw the stream from the lateral into the main ditch with sufficient force to prevent the deposit of silt where the lateral enters the main.

Use regular, manufactured union tiles. These can be had in almost any combination of sizes wanted, and are made to give the connection at proper angle. The connection is made in the process of manufacturing the tile, so that it has been burned after the union is made. This will give you a tight joint which will prevent dirt from entering the tile as will happen with the average home made union. If you make a union in the field, see that it is made good and tight. It can be covered with pieces of broken tile so as to protect it fairly well from the entrance of dirt. But it would be much better to seal the joint with concrete so as to make sure there is no hole thru which dirt or silt can enter the tile.



Manufactured "Y" or union tile with tightly sealed joint.

Making a turn Never change the direction of a ditch with a sharp or direct angle. Always make the turn in the shape of a part of a circle. This circle should have

The proper way to make a turn.

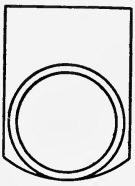
a radius of at least fifty feet, one hundred is better. A sharp turn or angle will seriously reduce the amount of water which will flow thru the drain in a given time. This means, furthermore, that it will correspondingly reduce the number of acres which will be drained properly by the ditch.

If the ends of the tile on the outside of the turn are more than one eighth to one quarter of an inch apart, this opening should be covered by placing over it a piece of tile the same diameter. This will help keep dirt from getting in thru this too large opening at the joint.

Making a joint The ends of the tile should meet each other squarely. If they are a little irregular, so they do not meet squarely thru the full circle, then they should be closest at the top so as to keep out dirt. Most of the dirt which gets into the tile comes in thru the top or the sides of the joint; very little, if any at all, comes in thru the bottom portion of the joint, except quicksand.

All the water which gets into a line of tile, enters it thru the joints between the tiles. It does not seep thru the walls of the individual tiles. Some men will argue that you should use a soft tile so that the water can get into the ditch. This is all bosh. All the water which would work its way thru the walls of even a very soft burned tile in a year will not be sufficient to carry off the surplus from even one fair sized rain. If you do not believe it, seal up the end of a tile water tight; stand it on end and fill it with water, cover the top and let it stand until all the water has soaked out of the tile. If you had to go without eating while it was soaking its way thru the tile, you would starve to death.

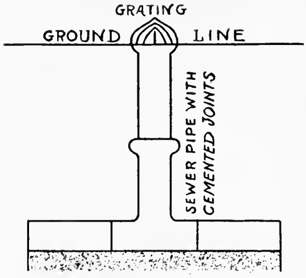
If you will fit the ends of the tile up to each other as close as possible· the space between the ends of the tile will be large enough to let the water into the ditch as fast as it works its way thru the soil. So snuggle them up as close as you can, so as to keep out the dirt.



Make the bottom of the ditch fit the curve of the tile.

Shaping the bottom The bottom of a ditch should be smooth, and with a uniform grade. It should be rounded to the same size or degree of curve as is the tile to be laid in it. This gives the tile a wide bearing surface on its bottom. This wide bearing surface on the bottom of the tile is especially important for large tiles which are laid to any considerable depth. The weight of the dirt which is piled on top of these large tiles in filling the ditches throws a

very considerable load onto them. If the tile rests on a flat ditch bottom, it will be crushed by a considerably less load of this kind than if it is laid on a bottom which has a curve of the same radius so the tile will fit into the bottom of the ditch as the axle of a wagon fits into the wheel hub.



A surface intake.

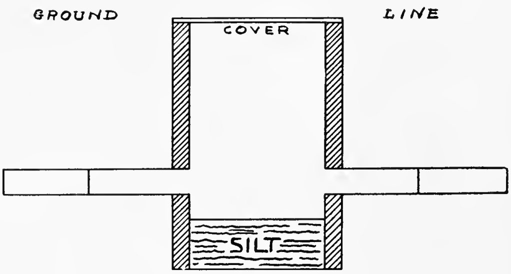
Surface intakes These inlets are merely branches which connect the tile with some spot on the surface where water collects and stands, without running away as surface flow. They admit this surface water direct into the tile instead of forcing it to work its way thru the soil to reach the tile. Some people place them in small ponds, or "impounded areas," in the fields. Others place them only in roadside ditches where for some reason or other all the surface water does not run off with the surface drainage.

These inlets should be made of sewer pipe with cemented joints, after the manner shown in the drawing. They should be covered with a metal grating to keep out weeds and trash. The best kind is the conical or "bee-hive" shaped grating. A post should be set firmly in the ground beside the inlet to prevent machinery from being driven over it and damaging it.

Simply filling a short stretch of the ditch up to the plow line with broken tile, crushed stone or gravel, does not make a good inlet. It never works satisfactorily. It either fills up or washes out. Use a real inlet, or none at all.

Silt basins Where tile are laid in a sandy subsoil, in quick sand or a fine silty loam, considerable quantities of sand and silt will get into the tile. Silt basins should be placed at the lower ends of such stretches of the ditch to keep this silt from going on into the lower stretches of the ditch or the mains which lie below. Wherever the grade of a main ditch is lowered materially so that the velocity of the tile water is slowed down, one of these basins should be placed to catch the silt which is dropped and keep it out of the ditch where it would be deposited if the basin is not provided. These silt basins also serve as inspection manholes for making occasional investigations of how ditches are working.

These silt basins are constructed on the principle of shallow wells which extend down a few feet below the bottom of the tile. The cross sectional area of the basin should be equal to from five to ten times the cross sectional area of the tile which empties into it. The flow of the water from the tile into this well or basin checks its velocity and causes it to deposit its silt



A good design of silt basin.

in the bottom of the basin. The water flowing out of the far side of the basin has been freed of the bulk of its silt so that the stretch of tile lying below is protected from any deposit of silt which would have occurred as a result of lowering the grade of the ditch at this point. After each heavy rainy spell, these basins should be inspected. If the silt has filled up to near the bottom of the tile it should be cleaned out. These basins should be walled up to prevent their dirt walls from caving in. An excellent way to do is to dig them circular and then wall them up with hard burned brick or silo blocks, which can be laid up quickly and easily. If dug square, they can be walled up with road plank. The trouble with this is that wood will decay in a few years from the alternate wetting and drying. If planks are used, they should first be painted with a coat of creosote or other water proofing paint to prolong their life.

Protect the outlets The outlet of all ditches should be protected against washing of the banks of the stream or open ditch into which they empty, and against damage by the trampling of live stock which may come to the mouth of the ditch to drink. A bulkhead should be built of stone or concrete. It is also well to build an "apron" under the mouth of the tile for the water to fall onto, and so prevent the flow of water from the tile from undermining the mouth of the ditch.

It is best to build these bulk heads as soon as the first few rods of ditch have been dug, so that the first tile can be laid tightly into it as the bulkhead is being built, and to protect the mouth of the ditch from being washed out while the system of tile is being laid. The first ten to fifteen feet of the ditch should be made of vitrified sewer pipe, or of iron pipe, because ordinary drain tile will disintegrate in a few years when subjected to the combined action of air and of freezing. This injury occurs only in the first few feet of the open end of the ditch, the rest of the ditch being undamaged by freezing if well burned tile are used.

The mouth of the tile should also be protected from the entrance of dogs and field animals. A very good protection of this sort consists of a hinged cover of light iron bars, or fine meshed woven wire fencing made of heavy galvanized iron wire. If this is hinged from the top, it will give under the force of the stream of water and so will not interfere with its flow. At the same time, it will swing back tightly over the mouth of the tile when no water is flowing thru. The open spaces in the fencing, or iron bars, permit one to look up into the open mouth of the tile to inspect it. By using a mirror, a beam of light can be thrown back into the tile so one can see for several hundred feet into a straight ditch and locate any obstruction which might have gotten into it.

CHAPTER XV.

What Tile To Use

Use only the best to be had, even tho you may have to pay a little more for it than you would have to pay for some other kind. It is utter folly to use an inferior grade of tile just because you can get it for a dollar or so less a thousand feet than you have to pay for the best grade. Look at it this way for a minute: When you go to the trouble and expense of putting in a system of tile ditches you do not want to do it all over again. You should not have to do it over again, nor should your children have to, if it is done right. You will not have to, and they will not have to, if you use a first class grade of tile and do a good job of laying it. But if you use a cheap, poor grade of tile, it is certain that at least your children will have to do the job over again; and it is almost as much of a cinch that you yourself will have to do it unless you are already well past middle age when you do it the first time. Not only do you want the system to last for years, but you want to know that there is no question about its working satisfactorily all the time.

You do not send a boy or a hired man off into a far field out of sight all alone to work on some important job unless you know that he is able to do that work, that he knows how to do it, and that you can trust him to do it all alone himself. For the very same reason, you should not bury tile out of sight in the ground to do important work for you unless you are sure that they are an efficient, durable grade of tile; unless you know that they are a grade of tile which will stand up for years, and even for generations.

The cost of the tile represents only about one third of the cost of tiling land, the various items of labor representing the other two thirds. By buying a cheap grade of tile you might be able to save a few cents a rod on the cost of the finished job. But by making that saving you practically insure that within a few years at least several of those cheap tile you bought so as to save those few pennies a rod will "go down" on you. By going down they clog all of the ditch above them and ruin enough crop in one season to pay all of the costs of laying the ditch they clogged up. In a few more years at the most, you will have to take up all those cheap tile you laid and lay new ones. This will cost you more than it cost to lay those poor tile in the first place, or than it would have cost you to lay good ones while you were at it. And what is even worse, in the mean time you have not had as efficient service out of your ditches as you should have had; and thereby you have lost money each year you were depending on these "broken reeds."

You simply cannot afford to be so foolishly economical as to lay inferior tile, or anything poorer than the best, simply to save a few dollars a thousand feet of ditch.

Buy of a reliable firm The firm manufacturing the tile you use is one of the surest guarantees possible as to the quality of the tile you are using. It is just like buying any other manufactured article. You should buy the product of an old, well established firm which has the reputation of putting out a large volume of good tile, and which has been doing it for many years in succession. The very fact that they are getting enough business to keep them going on an extensive scale year after year is, in itself, proof that their tile are good. The small, "neighborhood" manufacturer cannot afford the expensive machinery, skilled workmen, foremen and superintendents necessary to put out a high class product. Only the large manufacturer, who produces on an extensive scale, can afford this investment and operating expense necessary to make the highest grade of tile. Their large overhead costs of operation are spread over such a large volume of product that it amounts to only a small amount for each carload, or each thousand feet of tile. This enables them to put more money into the various processes of manufacture—and so put out a better quality of tile— than can the small scale manufacturer who sells his tile at the same price.

Because of the large scale on which he operates the large manufacturer is always able to give you immediate shipments of whatever size of tile you may want or need. He operates his factory the whole year around and lays up a big store of finished tile to meet the demands of the season when his manufacturing facilities cannot keep up with his shipments. His large capitalization enables him to do this. But the small plant cannot afford to carry this heavy load of money tied up in manufactured product stored in his yards. He often accepts orders for tile which he does not have on hand, and you have to wait until he can manufacture them, and then fills other orders which have accumulated ahead of yours, and such waiting is very apt to cause you considerable loss, often means a delay of several weeks.

Cement tile It may be possible to make good cement tile. But there is still room for an abundance of doubt on this question, and as to the advisability of using them—especially the smaller sizes which are made by what is known as the "dry mix" process. No tiling systems in which cement tile have been used have yet been in operation long enough to prove in actual practice that cement tile will last as long as it is known that good clay tile will continue to operate efficiently. So that the least that can be said on the subject is that their durability has not yet been proven in actual practice under regulation farm drainage conditions.

The chief advocates of the use of cement tile are the manufacturers of tile making machinery, not the manufacturers of cement. These manufacturers of tile making machinery have extensively advocated the use of small type machines by which they claim that a man can make his own tile right on his farm cheaper than he can buy them.

If you are seriously contemplating the use of cement tile, especially if you are thinking of making your own tile, here are some features of the problem which you should consider seriously before definitely deciding to do it:

Drain tile offer one of the most severe conditions which concrete is asked to withstand. It is asked to withstand the decomposing action of running water which is charged with more or less carbonic and other soil acids which exert a dissolving action of no mean effect on the cement contained in the tile. The mere fact that foundations, footings, piers, etc. of massive construction have stood for years, even tho buried in the ground much as tile are buried, is no proof that thin walled cement tile will stand up. These are massive and are saturated with standing water only. The tile walls are thin, are not only saturated with water, but are also subjected to the effects of running water; the flow of water greatly increases the rate at which the cement is dissolved out. Running water also has an eroding effect which materially adds to and aids the dissolving action of the water in its tendency to destroy the tile.

In order to reduce the labor cost to the lowest point possible, the smaller sizes of cement tile are made by the so-called "dry mix" process. The cement and sand are mixed together dry and then simply moistened with a small amount of water, just enough to hold the cement and sand mixture together after the jacket or mold is removed —which is within a minute or less after the mixture has been packed into the mold. And yet cement manufacturers constantly teach that in order to make a strong durable concrete it is necessary to use enough water to produce a "quaky" or a "slushed" mixture. In the manufacture of cement tile this sort of a mixture is used only in making the very large sizes of tile for use in main ditches.

Also, when cement manufacturers do discuss the making of cement tile they say you should not use a mixture thinner than one part of cement to three parts of coarse sand or fine gravel. To make a mixture this rich, or any richer, makes the cost so high that cement tile cannot be sold profitably in competition with high grade clay tile. The result is that manufacturers of cement tile use at least four, if not five or more parts of sand or gravel to one part of cement.

A cement tile factory can be put up with a small investment. The result is that the country is dotted with the ruins of abandoned cement tile factories. Individuals and small companies have gone into the business with a small invested capital and with little or no experience in drainage or the manufacture of concrete products. The superintendents and workmen have been local men who are not familiar with the important problems of materials, mixture and curing required in the manufacture of concrete products. After a few months, or a few years at the most, there comes a lull in their business and they quit it. If the tile you bought of them fails you in a few years, you have no means of collecting damages; the firm you bought of is out of business.

Large contracting firms which use a great deal of cement require that all cement used by them shall pass rigid laboratory analyses and tests. They frequently find it necessary to reject part or all of a large shipment because it is below the standard of quality required. Thus they carefully analyze and test their cement before using it because they realize the important part which the quality of the cement plays in determining the quality of the finished concrete which they produce. The cement tile factories scattered over the country cannot afford to

employ high priced chemists for this work and so do not use this care and precaution with regard to the cement they use. The result is found in much of the product they put out.

It is a waste of good money, and of good time as well, to attempt to make your own tile and save any money if you count your own time as worth any thing. You are not skilled in the work, and so cannot make them as rapidly as can even the most inefficiently operated factory. You have to buy the machinery and erect drying and curing sheds. The chances are ninety-nine to one that you do not have a gravel deposit that is at all good enough. Contrary to the advertisements of the machinery manufacturers, making cement tile is not a job at which you can work odd hours. To get even a half way decent quality of product, and get it at a reasonable labor cost, one must operate the plant in full day shifts. Then the tile must be watched carefully and watered freely and frequently for several weeks. At best, the home manufacture of cement tile is a delusion and a snare.

Clay tile The one kind of drain tile which has stood the test of time is made of clay or of shale. They are still working in this country, after three quarters of a century of continuous and satisfactory use. They are still working in Europe after a full century or more of use. So their quality and efficiency is known. There is no guess work about it.

Clay tile should be close grained and of fine "texture." They should be hard burned so they will absorb a minimum amount of water; remember that water enters thru the joints of the ditch, not thru the walls of the tile. Salt glazing is unnecessary, it adds no more strength than would a coat of paint, and often covers up a multitude of sins within the walls of the tile itself. "Vitrified" is a word which is used to conjure with by some manufacturers and salesmen of clay products, and it means far less in terms of service than the average user would have you believe it means. When clay is fully vitrified it fuses or melts into a continuous mass like glass. No drain tile are vitrified completely; if they were, they would not hold their shape in the kiln.

What is wanted is a tile which has been burned hard enough—vitrified to such degree, if you persist in wanting that word—that it will not flake or chip, will have a clear metallic ring, and be strong enough to carry the load placed on it. If vitrified to too great an extent, the tile become too brittle and crack and break too readily in handling and shipping, thus increasing the danger of getting cracked tile into the ditch.

There are two clases or kinds of clay tile on the market. One is made of the soft surface or "drift" clays of more or less impurities and irregularities in character. The other is made from the stonelike shales, or clay in a natural condition which resembles rock. The shales are finer grained than are the surface clays. They make a finer grained, more close textured—and consequently, when properly burned, more durable—drain tile than do the surface clays.

A more elaborate equipment of machinery, and greater labor and other costs of operation, are required to manufacture the shale tile than are required for the surface clay tile because of the stonelike

character of the shales. Surface clays are found in all parts of the country. This fact, coupled with the smaller investment and operating capital required, has caused small neighborhood plants to spring up extensively over the country. Available shale deposits are found only here and there. This fact, coupled with the large investment and operating capital needed, results in there being far fewer shale tile factories than surface clay tile factories, and these are grouped or clustered where these available deposits are to be found. These centers are noted for their extensive tile factories, as Battle Creek is noted for breakfast foods and Detroit for automobiles.

Every step in the process of manufacture must be watched carefully. Neglect in any one will give any one of several faults which will weaken or shorten the life of the finished tile.

1. The shale must be of such a nature as will adapt it to the various necessary processes of manufacture. It must be fine grained, or the tile will be coarse grained. It must be free from all particles of lime, or the particles of burned lime will slack when they become moist after the tile are laid, and will chip or crack the tile. The shale must be uniform in character thruout the entire deposit, or the tile will not be uniform in quality from one lot to another.

2. The shale must be ground fine, and thoroly "pugged" or mixed with water or it will come from the shaping machinery "laminated," or in layers which will burn in layers and so scale off or split afterward. When improperly pugged tile are burned in the kilns some spots or portions will burn more quickly than others and the result will be "internal strains" which will cause cracks to form inside the walls of the tile, or even clear thru them. These cracks may not form until after the tile are laid, just as you have known iron castings or lamp chimneys to break from no apparent cause when standing idle, or a broken casting to show an old internal crack which did not appear anywhere on the surface thus leaving only a thin shell of metal to be broken. The cause is similar, "internal strains." This pugging is one of the most vitally important steps in the entire process of manufacturing drain tile, it is the one in which manufacturers fail most often to do their full duty.

3. The shaping machinery must be accurate, or the finished tile will not be accurate in size. Faults in the machinery itself may cause laminations.

4. The "green" tile must be cured in curing or drying houses where the rate of drying may be controlled accurately. If the drying is not properly controlled, then the walls of the tile will not be uniformly dry thruout their entire thickness when they are placed in the kilns to be burned. When they are burned, internal strains will be produced just as was explained as resulting from improper pugging.

5. The burning must be done very carefully by skilled burners in properly designed kilns. Too low or too high temperatures at various stages of the burning process will produce a very inferior tile.

6. The contents of each kiln must be sorted very carefully after burning to remove all crooked tile; those that are cracked, or chipped; those that are "laminated"; those that are not burned hard enough; some of the more conscientious companies even sort out those that are white washed, a fault in looks only, not in quality.

CHAPTER XVI.

Why Denison Tile Are Best

Written by Amos P. Potts,
Ceramist of the Mason City Brick & Tile Co.

Here at Mason City, Iowa, we have an extensive deposit of clay and shale which is better adapted to the manufacture of drain tile than any other deposits known in this country. Combined with the quality of our raw materials is the fact that we have the most extensive drain tile manufacturing plants, and use the best process of manufacture, to be found in the world. Consequently we produce the most uniform, the highest grade, and the most durable drain tile manufactured in America. The result is that the Mason City Brick and Tile Company produces one seventh of all the drain tile manufactured in the United States.

The raw material which we use Our deposit of raw materials consists of the Hackberry clay and the Devonian shale. The Hackberry clay lies on top of the Devonian shale, but is not what is known as a "surface clay." It is what is left from the decomposition of an ancient deposit which was originally about one hundred times as thick as the present layer of clay. This

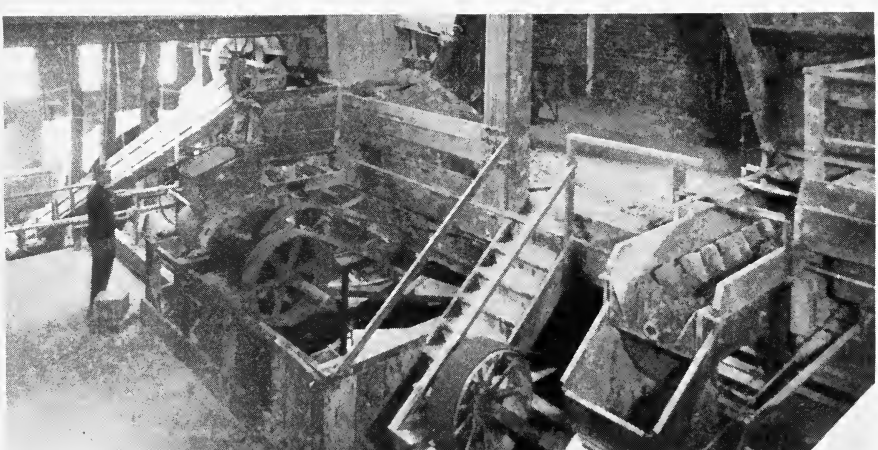
Mining the clay and shale used in making Denison Double Process Drain Tile.

leaves only the finest part of the original deposit, that which is best adapted to the manufacture of drain tile. This Hackberry clay is very fine grained, thus adapting it to the manufacture of a fine grained drain tile. As compared with the Devonian it is also what is known as "highly refractory," which means that it requires a higher temperature to melt it down and cause it to lose it's shape in the kiln.

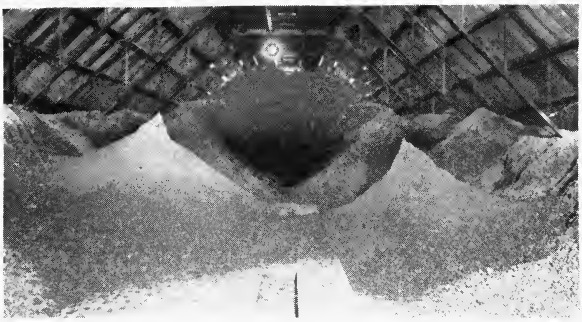
Our Devonian Shale is a clay which is stone-like in character. It is exceedingly fine grained, even finer than our Hackberry which is unusually fine for a clay. This deposit is about thirty feet thick. It is exceptionally uniform in quality thruout its entire thickness. This Devonian shale melts, or reaches "full vitrification," at considerably lower temperatures than does the Hackberry clay.

Other shale deposits of this country consist of a series of layers or strata which possess different characteristics. This makes it practically impossible for manufacturers using these deposits to make tile which are uniform in character and quality. But the unvarying uniformity of our deposits enables us to produce tile of equally unvarying uniformity in character and quality. This is very important to you. Each individual Denison tile you lay in your ditches is just as good as every other one you lay in those ditches; they are all the finest grained, closest fibered, truest shaped, strongest and most durable tile you can buy anywhere.

Why we mix these two materials Neither the Hackberry clay nor the Devonian shale, used by itself, is adapted to the economical manufacture of a high class drain tile. But by mixing the two together in accurately determined proportions we are able to produce a very fine grained, close textured, hard burned, durable drain tile which will serve you and your descendants faithfully for generations. If this were not so we could not now be manufacturing one seventh of the nation's drain tile output.



The first grinding of the clay and shale.



Ground clay stored in curing shed until taken to the mixer or pugg mill.

The Devonian shale is so exceedingly fine grained that it must be mixed with something else which will give it the necessary frame work to prevent the formation of "laminations," or thin layers one upon the other, in the process of molding the tile. The Hackberry clay is enough coarser than the Devonian shale to furnish this necessary frame work to prevent lamination; and yet it is not sufficiently coarse grained to produce a coarse grained tile. Only sufficient of the Hackberry is used to furnish this framework.

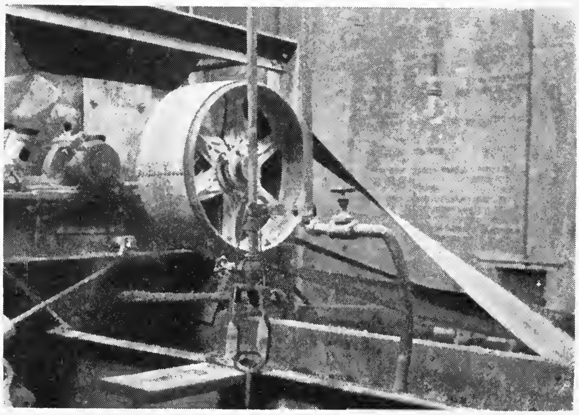
The Devonian melts at a lower temperature than does the Hackberry. By burning our tile to a sufficiently high temperature to produce a high state of vitrification in the Devonian portion of the tile we have not heated it enough to melt down the Hackberry "framework." This enables us to produce a very hard burned tile, with a high degree of vitrification, without any danger of the tile melting down and losing its shape, or becoming brittle and easily broken.

Thus Denison tile are not only hard burned, but they are fine grained, close textured, uniform in size, straight and cylindrical in shape; tile which are easy to lay, and which last for generations. By means of this mixture of Hackberry clay and Devonian shale which we use, Denison tile are finer grained, more compact, straighter and stronger than is made from any other deposit of shale or of clay.

Advantages of our raw materials

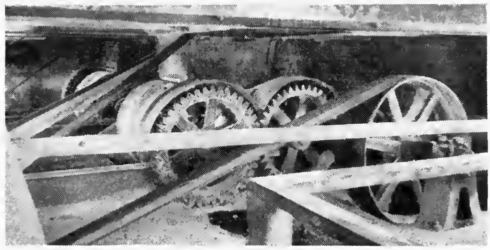
1. We have only two kinds of raw materials to handle. These are very uniform in quality and character.

2. Other Iowa and Minnesota deposits contain from six to twelve kinds of shale which must be



The pugg mill, where the clay is mixed with water and kneaded into a very uniform mixture.

mixed with great care to give even a fairly good grade of product.



Between the first and second pugging the mixture is run between these powerful steel rollers.

3. This greatly simplifies our problem of getting the proper mixture to give us a high grade finished product. It is just that much insurance to you that in buying Denison tile you get the best drain tile made.

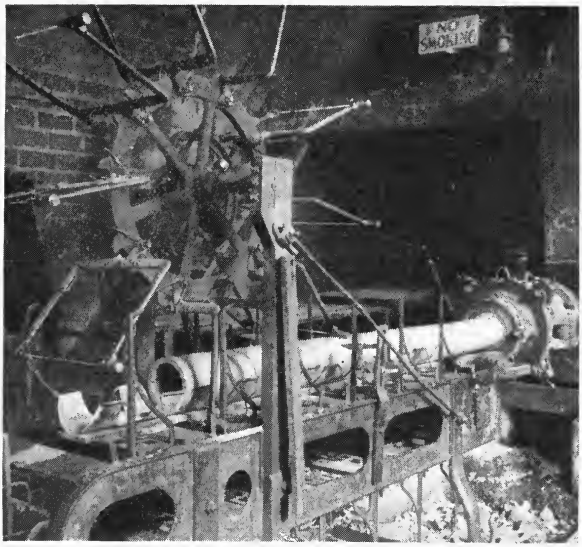
4. The exceedingly fine grained character of both of these materials makes it possible for us to produce a finer grained, closer textured and more compact tile than can be produced from any other deposits.

5. The Hackberry clay and the Devonian shale mix more readily with water when "pugging" or preparing them to go to the molding machines than do other Iowa and Minnesota deposits. This decreases the danger of weak spots in the walls of our tile resulting from "internal strains" explained in the last chapter of Mr. King's book.

Our "double process" of manufacturing tile Our Hackberry clay and Devonian shale are ground to a very fine powder and mixed in the proper proportions necessary to produce tile of the desired quality. They must be ground to this fine powder so they will mix thoroly with each other and with water. This thoro mixing is necessary so that they will mold without laminations or cracks being formed, and so that they will be of a uniform character thruout when burned.

After preliminary grinding the mixture is shredded and stones removed by being passed through these powerful disintegrators.

Next they are thoroly "pugged." This pugging consists of mixing the powdered clay and shale with a definitely known and carefully controlled quantity of water, and thoroly "working" the mixture as dough is worked or kneaded in the making of bread. This pugging is done so thoroly that each individual grain of the powdered material, so tiny that a microscope is necessary to



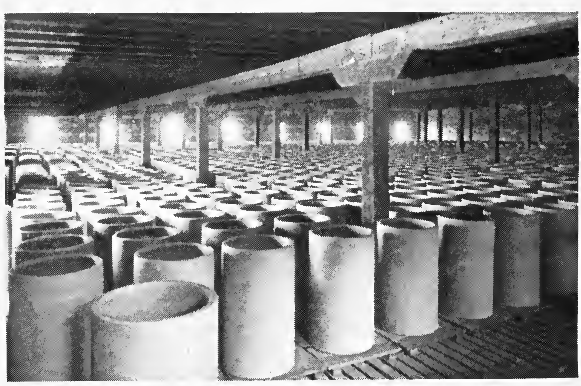
After a second pugging the mixture is forced through this molding machine, where a continuous tube of clay is formed which is automatically cut into uniform lengths.

see it, is coated with a film of water.

Then this pasty mass is run thru a set of heavy steel rolls to crush any lumps which may have been formed during the pugging process. From these rolls it is taken to a second pug mill and given its second pugging. Either the first or the second pugging, which we give the material, is alone as much pugging as other manufacturers give their material. This second pugging is what gives our tile their name of the "Denison Double Process Tile."

After this second pugging, the now thoroly prepared clay is sent to the molding machinery. Here it is molded and cut into the proper sizes and lengths of tile and sent to the drying or curing sheds. In these sheds the temperature and air movements are under perfect control at all times. This gives the careful, uniform drying which is so necessary in the manufacture of high grade tile.

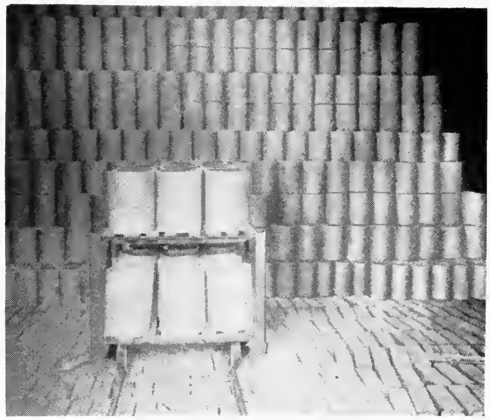
When properly dried or cured, the tile are stacked in the kilns and put thru the burning process under the supervision of highly skilled burners. In these kilns we use a specially designed system of drafts which insures a constant supply of heat at the desired temperature uniform thruout the entire space of the kilns. In this way all of the tile in a kiln



Before being put into the kiln, the tile are cured in the drying shed, where temperature and air movement are under complete control.

are burned to a very uniform degree of hardness.

After the process of burning has been completed, the kilns are allowed to cool slowly. When the contents are cooled, the tile are removed and graded carefully to remove any which have been damaged or mishapen in any way in handling. Our sorting and grading is very rigid. It is so rigid that only tile which are true to size, straight and uniform in diameter, free from all cracks and laminations, sound and thoroly hard burned, ever reach our storage yards for shipment to our customers.



From the drying room the tile are taken to the kiln, stacked carefully and burned with the greatest scientific accuracy.

The advantages of our double process of manufacture

1. The double pugging which we give our finely ground raw materials absolutely insures the proper moistening and mixing of the two grades of raw material which we use. The entire mass is of a highly uniform character thruout when it goes to the molding machinery. This, in turn, insures a highly uniform grade of tile for shipment to our customers.

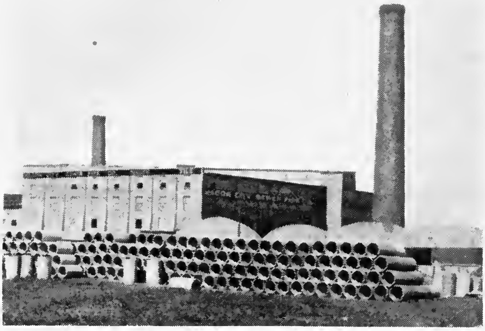
2. This extra pugging reduces to the minimum all chances of the formation of "laminations," or the "internal strains" which Mr. King explained thoroly in the last chapter of his book.

3. This extra pugging also gives a very compact, fine grained and close textured tile wall which is very important in determining the length of the useful life of the tile.

4. Our controlled method of drying insures "safe drying." It insures the tile against any internal cracks which do not show on the surface, or those external cracks which extend clear thru the walls of the tile. It also is one more insurance against the formation of any internal strains which give hidden weaknesses to the tile. These are all faults which are found extensively

After cooling slowly at the close of the burning process they are stacked in the storage yards to await your orders.

in clay tile which are simply dried in open sheds where the rate of drying is beyond the control of the manufacturer and is entirely dependent on the condition of the weather.



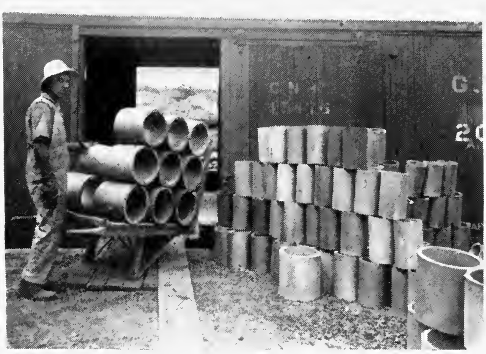
A storage yard at one of our eight factories.

5. Our extensive output of some ten thousand car loads of drain tile a year permits us to employ a full force of expert superintendents and workmen from one year's end to another. These men give every step in our process of manufacture a more costly and careful supervision and inspection than can the smaller scale manufacturer whose overhead costs such as these, must be charged up to a much smaller volume of output. This large volume output of ours, the largest in America, enables us to sort our product much more rigidly and mercilessly than can a company with a small volume of output, and still pay ourselves a reasonable rate of profit on our investment.

Why you should buy Denison Double Process Tile

1. Because it is the finest grained, closest textured, strongest, longest lived, straightest, most uniformily sized and shaped tile on the market.

2. Because it costs you no more than the best tile sold by other firms, even tho none of them is as good as the Denison Double Process Tile.



Within 24 hours after an order is received at our office it is loaded onto the cars and shipped to the purchaser.

3. Because our immense volume of output, and the fact that we operate twelve months in the year, insures that we can always furnish you any tile you want, in any quantity you want it, as quickly as it is possible for freight service to get it to you.

4. Because the five steam railroads which dominate the freight industry of this section pass thru Mason City. This gives us the best freight shipping facilities west of Chicago.

One reason why we can always give you prompt shipment.

5. Our large resources and financial reliability, and our over thirty years of reputation for fair dealing, insure that you will get nothing but the highest class product, and the squarest possible treatment from us.

MASON CITY BRICK AND TILE CO.

Mason City, Iowa.

A bird's-eye view of one of our factories.